OPERATION BARBAROSSA:

the Complete Organisational and Statistical Analysis, and Military Simulation

VOLUME I

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List of Diagrams, Graphs and Tables

List of Abbreviations

A	Accuracy
A Cars	Armoured Cars
AA	Anti-Aircraft and Relative Anti-Aircraft Value
AAB	Anti-Aircraft Battalion
AAC	Anti-Aircraft Company
AAG	Anti-Aircraft Gun
AAMG	Anti-Aircraft Machine Gun
AAP	Anti-Aircraft Platoon
AAS	Relative Assault Attack Strength
AcCo	Armoured Car Company
ADS	Relative Assault Defence Strength
AE	Aircraft Mounted Weapon Effect
AFV	Armoured Fighting Vehicle
AP	Armour Piercing
APC	Armour Piercing Capped
APC	Armoured Personnel Carrier
APCBC	Armour Piercing Capped Ballistic Capped
APer	Relative Anti-Personnel Value
ArB	Artillery Battalion
ARM	Relative Armour Defence Strength
ArP	Artillery Platoon [or Battery)
ArR	Artillery Regiment
ASE	Ammunition Supply Effect
ASig PI	Armoured Signal Platoon
AT	Anti-Tank and Relative Anti-Armour Value
ATB	Anti-Tank Battalion
ATC	Anti-Tank Company

ATG	Anti Tank Gun
ATP	Anti-Tank Platoon [or Battery
ATT	Relative Overall Attack Factor
B Sup	Battalion Support
BicBat	Bicycle Battalion
Br	Bridging
BrB	Bridging Battalion [pontoon)
BrC	Bridging Company [pontoon) or Bridging Column [pontoon)
BrCB	Bridge Construction Battalion
Bri Sup	Brigade Support
BrP	Bridging Platoon [pontoon)
Cav	Cavalry
Cav B	Cavalry Battalion
Cav Brig	Cavalry Brigade
Cav Reg	Cavalry Regiment
CavP	Cavalry Platoon
CavS	Cavalry Squadron
CavSC	Cavalry Support Company
CavT	Cavalry Troop
CL	Aircraft Ceiling Effect Factor
Cons Bat	Construction Battalion
CPF	Concealment and Protection Factor
D	Deployed
D Sup	Divisional Support
DDF	Defensive Dispersion Factor
DEF	Relative Overall Defence Factor
DUR	Aircraft Durability Factor
EnB	Engineering Battalion
EnC	Engineering Company
Eng	Engineering
EnP	Engineering Platoon
EnR	Engineering Regiment

FCE	Fire Control Effect
FDE	Relative Fortification Destruction Effect
FILARM	Fully Integrated Land and Air Resource Model
GPMG	General Purpose Machine Gum
Gun/Can	Gun/Cannon
HAR	Heavy Artillery Regiment
HCavS	Heavy Cavalry Squadron
HIC	Heavy Infantry Company
HMG	Heavy Machine Gun
How	Howitzer
HQ	Headquarter
HR Sqd	Heavy Rifle [or Infantry) Squad
HRC	Heavy Rifle Company [w HMGs &/or mortars)
I Bat	Infantiy Battalion
I Div	Infantry Division
I Reg	Infantry Regiment
I Co	Infantry Company
ILARM	Integrated Land and Air Resource Model
InG Co	Infantry Gun Company
InG P	Infantry Gun Platoon [or Battery)
[P]	Infantry Platoon
LAR	Light Artillery Regiment
LMG	Light Machine Gun
LR Sqd	Light Rifle Squad
LS	Landesschutzen, [Local Defence Unit)
LS Reg	Landesschutzen Regiment
MAR	Medium Artillery Regiment
MBE	Multi Barrelled Weapon Effect
MD	Mobilised and Deployed
MDS	Minimum Divisional Size
MFM	Motorised Mobile Fighting Machine
MG Bat	Machine Gun Battalion

MG/Art Bat	Machine Gun and Artillery Battalion
MgCo	Machine Gun Company
MgPl	Machine Gun Platoon
MGS	Machine Gun Squadron
MGT	Machine Gun Troop
MMG	Medium Machine Gun
MND	Mobilised and Not Deployed
MoB	Mortar Battalion
MOB	Relative Overall Mobility
MoC	MortarCompany
MoCyBat	MotorCycle Battalion
MoCyCo	MotorCycle Company
MoCyPl	MotorCycle Platoon
MOF	Battlefield Mobility Factor [for land units and aircraft)
MoP	Mortar Platoon [or Battery)
Mor	Mortar
MP	Military Police
MPBat	Military Police Battalion
NerWBat	Nerbelwerfer Battalion
OCPC	Overall Combat Power Coefficient
00B	Order of Battle
OPQ	Main-gun Optics Quality
OTF	Open Top Factor
PiC	Pionier Company
PILARM	Partially Integrated Land and Air Resource Model
PR	Protection Factor
PTS	Number of Potential Targets per Strike
Pz	Panzer
QJM	Quantified Judgement Model
R	Effective Combat Ranges or [Aircraft) Combat Radius, and Replacements

R Bat	Rifle Battalion
R Div	Rifle Division
R Reg	Rifle Regiment
R Sqd	Rifle [or Infantry) Squad
R Sup	Regimental Support
RA	Range of Action for land units, or Radius of Action for aircraft
RArB	Rocket Artillery Battalion
RArP	Rocket Artillery Platoon [or Battery)
RCo	Rifle Company
ReB	Reconnaissance Battalion
ReC	Reconnaissance Company
ReP	Reconnaissance Platoon
RF	Rate of Fire
RFE	Rapidity of Fire Effect
RIE	Relative Incapacitating Effect
RL	Reliability Factor
RN	Range Factors
ROCP	Relative Overall Combat Proficiency
RPl	Rifle Platoon
SaB	Sapper/Pionier Battalion
SaC	Sapper Company
SaP	Sapper/Pionier Platoon
SapS	Sapper Squadron
SchBat	Schnell Battalion [Fast Battalion)
SDE	Supply Distribution Efficiency
SDF	Supply Demand Factor
Sig B	Signal Battalion
Sig C	Signal Company
Sig PI	Signal Platoon
SMG	Sub Machine Gun
SMGC	Sub Machine Gun Company
SPA	Self-Propelled Artillery Factor

SpMvr	Aircraft Maximum Speed and Manoeuvrability Factor
Sqd	Squad
SSF	Shape and Size Factor [for land units and aircraft)
StuGC	StuG Company [German assault gun co)
StuGP	StuG Platoon [German assault gun platoon)
TankB	Tank Battalion [or Panzer Battalion)
TankC	Tank Company [or Panzer Company)
TankP	Tank Platoon [or Panzer Platoon)
TankR	Tank Regiment [or Panzer Regiment)
TankS	Tank Squadron
TBE	Turret Basket Effect
TCE	Turret Crew Efficiency
TDi	Typical Target Dispersion Factor
TDR	Rotating Turret y/n, and Turret Drive Reliability
TID	Target observation and Indicator Devices
TNDM	Tactical Numerical Deterministic Model
TOE	Tables of Organisation and Equipment [Soviet - Shtaty and German - KStN)
Tra	Transport Infrastructure
TRF	Tactical Responsiveness Factor
W	Wach [Watch)
W Bat	Wach Battalion
WCPC	Weapon Combat Power Coefficient
WHT	Half Track/Wheeled Effect

Introduction

On 22nd June 1941 the Wehrmacht launched the largest invasion in recorded history, under the code name Operation Barbarossa. Operation Barbarossa needs no introduction to students of the Second World War, as it is unrivalled in military history for size, speed of operations, and the magnitude of its geographic objectives. The Wehrmacht's objective was no less than the complete defeat of the USSR, a nation possessing by far the largest army and air force in the world at that time. This study focuses on the period from 22nd June to 31st December 1941: the period when the Soviet Union came closest to defeat, and arguably the only period when Germany could still win WWII outright. Since the end of WWII, debate has raged about the key operational and strategic decisions made by the German and Soviet high commands, especially during the critical period from July to September 1941.

Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation is essentially the history of the Axis invasion of the USSR during 1941, expressed in the form of a detailed statistical analysis and an accompanying military simulation methodology. The objective of this work is to create the most historically accurate, advanced and comprehensive quantitative model yet, of the first six months of the largest and costliest military campaign in history (encompassing Operation Barbarossa and Operation Typhoon). The work includes full analyses of the belligerents' military, economic and logistical structure and capabilities, as related to their war effort on the East Front during 1941. This includes extensive data on: the structure of the relevant military and security organisations (land, sea and air), the available equipment and personnel, analyses of the weapons used, transport, logistics, economic production of war materials, mobilisation, and the replacements available and used during the campaign.

In addition, this enormous amount of historical data is organised and presented in such a way as to be 'ready' for incorporation into a

comprehensive computer based military simulation of Operation Barbarossa. The work therefore includes an analytical and quantitative based methodology for creating a mathematical model of a country's armed forces and its overall war effort. This is the bulk of the content of Volume I. The methodologies defined in this work are designed to be generic, in that they can be employed to create a military simulation of a campaign other than Operation Barbarossa. One of the distinguishing features of this work is that it formalises and documents a military simulation methodology extending from the tactical to the strategic level. This includes a formal methodology to calculate and assess an armed force's Relative Overall Combat Proficiency (ROCP), detailed in Volume V and applied to the forces involved on the East Front during 1941.

However, the user is not obliged to follow or even understand the details of the quantitative methodology used if they so choose. *Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation* is structured so that the user does not need to be familiar with military simulation technology or terminology: the historical data is presented and referenced for the user to conduct their own research or analyses, or extract specific historical data regarding the campaign. The analytical methodology employed is mostly transparent to the user in subsequent volumes (see below), and they may not even be aware that it is being employed. Nevertheless, the analytical discipline enforced by the methodology is present at each stage, and all the belligerent nations and their armed forces undergo the equivalent detailed scrutiny.

The work spans the disciplines of military history, operational research, applied physics and mathematics, statistical analysis, and analytical methodology (usually relating to modern military simulations or war gaming). *Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation* does not assume the reader has detailed knowledge of the history of the East Front in WWII or extensive knowledge of the disciplines mentioned.

The key rationales behind this work are:

- To bring together an immense amount of information from many disparate sources, and present it in the form of a large 'data-

warehouse' in a single work. The professional researcher or amateur scholar of WWII is provided with a comprehensive data source, containing the details of all the armed forces involved on the East Front from 22nd June to 31st December 1941. Currently there is no single source detailing the actual land, air and naval forces involved in Operation Barbarossa and Operation Typhoon.

- To fully analyse the belligerents' economic and logistical capabilities, as related to the East Front in 1941 and in the strategic context of their overall war effort.
- To bring in-depth quantitative analyses to bear on the most probable outcomes resulting from different (historical) operational and strategic decisions, by the German and Soviet high commands during 1941. It presents the advanced student of this campaign with a mechanism to quantitatively analyse in-depth, the actual forces involved, and much more significantly, to examine the probable outcome of various 'what if' scenarios. In so doing, many of the historically accepted myths surrounding Operation Barbarossa are exposed, while other less appreciated historical factors are shown to have been far more significant than commonly perceived.
- To provide the user with a generic methodology for researching, cataloguing and building the elements needed to create a realistic simulation of a historical military event.
- To demonstrate the application of quantitative analysis to military history (as opposed to largely qualitative analyses), and to demonstrate the potential power of modern military simulations in the study of military history. Selecting the largest land campaign in history as the historical case study, demonstrates the scalability of the methodology employed. In addition, incorporating the multitude of interrelated factors and circumstances faced by each of the belligerents on the East front during 1941, makes it evident how sophisticated and historically accurate operational-strategic military simulations provide a most powerful method of studying military history available today. In so doing, *Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation* produces a new

perspective on a very famous, immensely important and tragic historical event.

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Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation is separated into six volumes as follows:

1. Volume I - The Concepts and General Structure of the Integrated Land and Air Resource Model (Part I), and The Methodology Used for Analysing Weapon System Effectiveness, and the Structure of the 1941 Soviet and Axis Resource Database (Part II).

2. Volume IIA and IIB - The German Armed Forces (Wehrmacht), Mobilisation and War Economy from June to December 1941.

   The size of the Volume II dictates it is published in two parts. The table of contents for Volume IIA is shown in Appendix C, and the table of contents for Volume IIB is shown in Appendix D.

3. Volume IIIA and IIIB - The Soviet Armed Forces, Mobilisation and War Economy from June to December 1941.

   The size of the Volume III dictates it is published in two parts. The table of contents for Volume IIIA is shown in Appendix E, and the table of contents for Volume IIIB is shown in Appendix F.

4. Volume IV - The Finnish, Rumanian, Hungarian, Slovakian and Italian Armed Forces Involved on the East Front in 1941.

5. Volume V - Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces on the East Front during WWII.

6. Volume VI – The Science of War Gaming, and Operation Barbarossa, the Complete Operational - Strategic Level Simulation from 22nd June to 31st December 1941.

Volume VI, the final part of the work, will include the actual Operation Barbarossa simulation. [1] This uses the methodologies and most of the

historical data presented in the preceding volumes. Using the work and data in the simulation as a historical reference, the user is able to wander through this momentous historical event, changing variables if desired, and still be in context. This allows close examination and analysis of almost all the military aspects associated with Operation Barbarossa.

Further detailed information on Operation Barbarossa, changes of publishing schedule for impending volumes, and ongoing content updates, can be obtained from the website operationbarbarossa.net.

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Finally, it is worth stating that *Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation* is a massive project, and one which is likely to be ongoing, reviewed and updated for many years to come. Research for this project goes as far back as the 1980s, with the 1990s and the opening of many of the Russian (ex-Soviet) archives as an enabling milestone. However, there are still many areas of contention and missing detail (especially Russian and ex-Soviet areas), and in this regard the details of the work may never be 'complete'. Nevertheless, these updates and changes will now be relatively minor, and although they may be pleasing to include for the military history purist, they would not have significantly affected the outcome of Operation Barbarossa at the macroscopic operational-strategic level.

Is all this research and work worth the effort for one campaign during WWII? Consider that the Axis invasion of the USSR in 1941 was by far the largest land invasion in recorded history, and one which ultimately led to the greatest loss of human life ever experienced in a single campaign. In addition, this campaign was by far the most decisive of WWII, and the one in which the Axis powers came closest to outright victory. Ultimately, over 70% of the German Army's WWII casualties were sustained on the East Front, while Soviet military casualties suffered while fighting the Axis powers in the western USSR amounted to a staggering 29 593 000 persons. Of this number, the latest studies by Russian scholars (in 2017) indicate that at least 14 654 000 were irrecoverable losses (killed, captured or permanently missing). Notwithstanding the huge Western Allied war effort,

there can be no doubt where the centre of gravity of the fighting during most of WWII was, and where the outcome of WWII mostly hinged.

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[1] At this time it is envisaged that it will employ The Operational Art of War (TOAW, currently version III) system, developed by Talonsoft and currently marketed by Matrix Games. If a superior system becomes available, especially one where the space and time scales can (also) be altered, then this will be reviewed. The necessary ‘scale’, to do justice to *Operation Barbarossa: Complete Organisational and Statistical Analysis, and Military Simulation*, is a minimum of 8km per hex and one day (24 hour) turns. The reasons for this, and the many pitfalls of inappropriate space-time scales in military simulations, are also reviewed in Volume VI.

Part I
The Concepts and General Structure of the Integrated Land and Air Resource Model

1. Studying Military History Using Operational – Strategic Simulations

Someone once asked me how I would define Physics in simple terms? After some thought, I said it was "Creating mathematical models of the real world". If I was to define military simulations in equally simplistic terms, I would say it is "Creating mathematical models of the military world". Physics uses mathematical models to predict the most probable outcomes in the physical universe (our real world), while military simulations use mathematical models to predict the most probable outcomes in historical and future battles and campaigns. Today military simulations are one of the most powerful and sophisticated tools available to serving officers for training, and the assessment of the probable outcome of complex military operations.

The term 'war game' is popularly used to describe even the most sophisticated military simulation. Essentially a war game is a military simulation with humans used to control key elements of a force's command and control. The level at which the human decision maker is introduced into the simulation depends on the particular simulation design and its objectives.

Most military simulations focus on one of four levels: specifically the tactical, tactical-operational, operational or strategic levels. In part 4 of this chapter we will focus on these levels in more detail. In most military simulations the human decision maker controls the forces at a particular level, while the other levels are generally simulated by the mechanisms within the military simulation. Larger and more sophisticated military simulations enable human command and control at multiple levels. Consequently in some sophisticated war games the simulation is only used for recreating the physical environment, specifically simulating factors such as the physics of the weapons involved, the various communication infrastructures, and the force's logistics. In this case all decisions (on both

sides) are made by human interaction and no tactical, operational or strategic decisions are made by the simulation's programming.

In this chapter we will briefly examine the history of military simulations or war gaming, its main uses, and why it is one of the most powerful (and under used) methods of studying military history available today. A description of the different categories of war games follows, with some detail on their main focus and the mechanisms used.

1) The Evolution of Military Simulations and War Gaming

Some would consider chess to be one of the earliest forms of war gaming. [2] Although the moves and rules in chess are abstract and not based on reality, chess does have some war gaming features appropriate to ancient times. These include: defined pieces (manoeuvre units) each with a fixed capability (mobility), defined starting positions (deployment), fixed terrain (the chess board), and turns with a time limit and poor command and control (represented by players moving only one piece per turn). These simple rules represent the fact that soldiers in ancient times had defined roles, usually deployed in lines at the start of a major battle, usually fought on clear ground and had limited control of their forces once the battle started. In the 17th century the first 'modern' war games appeared. Like chess, these early simulations were still rather abstract, but they now used real terrain representation and the playing pieces more accurately modelled contemporary military capabilities.

Throughout history men such as Sun Tzu, Machiavelli, Jomini and Clauswitz tried to formalise the theories and principles of war, and provide a 'formula for success'. These were almost all based on studying historical battles, looking for the common underlying reasons for success and then setting these out as principles to adhere to in future wars. These principles haven't always passed the test of time: changing culture, technology and size of the battlefield mean principles valid at one level of battle may not be valid at other levels. For example, Clausewitz, who was admittedly more interested in the philosophical aspects of war, stated that "defence is the stronger form of combat". From a common sense view point this would appear to be obvious and Clausewitz's principle has permeated military

thinking for decades. Even today many authors believe a defending force should automatically suffer far fewer overall casualties. However, although defence may be stronger tactically, stubbornly maintaining a defensive posture or being forced to maintain a defensive posture, can be disastrous at the operational and strategic level. This has often proved to be the case historically, and especially during WWII. [3] Similarly, the often used phrase "attack is the best form of defence" has proved to be unfounded in modern mechanised war. The fact is that attack is only the best form of defence under certain conditions and depending on many factors which are not always readily apparent.

As these writings and philosophies developed, the professional military began to take more notice of war gaming as a proper military tool: it soon became apparent that with fixed principles plus a model of the real world (the simulation), one could predict the probability of success better than using purely qualitative (i.e. non-mathematical) analysis. In the early 19th century, the Prussians developed the first detailed and realistic war games. [4] The Prussian Army developed a series of war games from studying historical battles, and used them for training, planning and testing new types of military operations. Most military simulations during this period confined themselves to single battles, but later, entire campaigns were simulated. These enabled more sophisticated parameters such as transport and logistics to be modelled and practised. By the 1870s most European armies had identified the potential of military war gaming by examining the Prussian efforts, but none developed it to the same degree. No doubt the Prussian successes in the Franco Prussian Wars, and the phenomenal organisational abilities of the German General Staff in relation to logistics in the first world war, were to some extent attributable to their prowess at war gaming. [5]

By World War II the German Army had developed war gaming to a standard where almost every major offensive operation was simulated to assess the chances of success, to iron out unforeseen factors, examine logistics and to develop contingency plans. The Army conducted war games, sometimes referred to as "map exercises", at theatre, army group, army and panzer group levels. [6] The form of these manual simulations was very similar to the more sophisticated board games of today. Operation

Barbarossa was no exception, and at the beginning of September 1940 Lieutenant-General von Paulus took over the co-ordination of all preparatory work of the Army General Staff involved in preparing an operational plan for Barbarossa. [7] His report used information from operational studies by Marcks and von Loberg. [8] On 23rd November 1940 the first war game to test Soviet responses was ready. These and other war games continued through December 1940, testing logistics, terrain, strength of required forces etc. In addition to General Staff war games, Army Groups conducted their own tests. Between 9th and 10th April 1941, Army Group Centre HQ at Posen (under von Bock) conducted major war games, primarily focused on how to ensure the bulk of Soviet forces in the Western Military District were to be prevented from withdrawing. [9]

The Soviets, British and Japanese also used war games in World War II, and war gamed many major offensive operations. Surprisingly, the US Army initially lagged behind the other major powers in this field, and only the US Navy regularly used military simulations. [10] Probably the most famous Soviet war game in the pre-Barbarossa period was carried out in the first week of January 1941. The war games were organised under the supervision of Defence Commissar, Marshal S.K. Timoshenko and Chief of the General Staff, General K.A. Meretskov. The war game was to test if an 'Eastern Force' commanded by Colonel-General D.G. Pavlov (representing the Soviet Army), could halt an attack by a 'Western Force' commanded by General Zhukov, in the area north of the Pripet Marshes. The aim of the war game was to show that the Eastern Force would be strong enough to halt the Western Force, and then to launch a successful counter-offensive. The war game turned out to be a major victory for the Western Force, which launched three powerful breakthroughs and destroyed the bulk of the Eastern Force. Stalin was so annoyed that he dismissed Meretskov and replaced him with Zhukov. [11] This incident reveals how seriously war games were taken by the Soviets, and it's a pity Stalin (and the Stavka) took more notice of the people involved than the actual results of the war game. It comes as no surprise to serious war gamers that almost all the Soviet and German war games, conducted in the six months before Operation Barbarossa, produced similar results to the historical result from June to August 1941.

In the post-war period the major developments in military simulations involved the application of computers, and developments in the areas of operations analysis and systems analysis. The constraint of manual (map based) simulations has always been the limited number of manual calculations that could be performed per turn and storing the 'status' of each unit over time. For example, manual simulations require the movement allowance, readiness, supply state and strength after combat, of each manoeuvre unit to be calculated and stored for each turn. If there are thousands of units then the simulation requires tens of thousands of calculations per turn, and millions of calculations per campaign. The result is that tactical (map based or board) war games tend to focus on small areas and fewer units, while operational or strategic war games tend to have large scales, large manoeuvre units with limited numbers of 'value steps', and long times frames per turn.

The development of computers meant the calculation rate and dynamic data storage could be dramatically increased: every unit's readiness, supply, combat damage, movement allowance, etc, could be calculated every minute if need be. Furthermore, far more sophisticated combat models could be implemented with many more factors included, and the interrelationship between parameters could be fully simulated. For example, when a unit moves it losses some readiness as the unit dispersion increases and some equipment is lost due to breakdowns. The readiness loss is a function of the transport available, distance moved, terrain, weather, and supply and support infrastructure. The computer can almost immediately calculate the readiness loss for each kilometre moved, while still taking into account all these variables. In most manual war games 'unit readiness loss due to movement' is simply not simulated, although some use abstract rules to partially represent these effects.

At this time (the 1960-70s) military simulations started to suffer from the same illusion plaguing other complex system modelling: namely that with massive computing power and brilliant mathematical theory, military simulations should be able to exactly predict outcomes of future battles and campaigns. As time has passed we have realized that operations and systems analysis may not be as reliable and accurate as once hoped, although it can still be relatively precise. Experience and further

developments in disciplines involving data analysis (e.g. data warehousing), has shown that not every aspect of any ‘real world’ system can be simulated or predicted. This has led some commentators to denigrate mathematical modelling as a tool in general, and specifically to say that military simulations cannot predict outcomes with certainty. However this argument is feeble and disingenuous because only God can predict anything with certainty! All mathematically based tools used for analysis and prediction, do not need to model with absolute accuracy or predict certain outcomes. If a military simulation (historical or otherwise) achieves even a 50% solution in terms of predicting the details of a battle’s outcome, then it is still well ahead of any qualitative based analysis using ‘educated’ guess work. The problem of accuracy in military simulations remains a trade-off between the complex nature of war, and the availability of time, resources and computing power.

Today (map based) manual war games are not considered precise enough for the needs of the professional military. It is apparent however that history based manual war games, although relatively imprecise in some aspects, still achieve a 70-90 % solution. This is accurate enough to be useful and still provides a far more accurate historical account of a battle or campaign than a purely qualitatively bases analysis. The advent of ever more powerful PCs and combat models, means the millions of calculations per turn can be done relatively quickly. This does not necessarily mean exact outcomes can be predicted, but pursuit of the ‘99 percent solution’ is possible today. [12] This of course, assumes ‘intelligence received’ is up to the required level if planning a future campaign, or ‘historical research’ is up to the required level if analysing a historical campaign. The reader can be sure that the 1990 Gulf War and the 2003 invasion of Iraq were war gamed, and that the Coalition commanders had a very good idea of their chances of success with their chosen strategies.

Today, the use of military simulations and war gaming generally falls into one of four main categories. They are:

1. Prediction of future outcomes, with or without data from historical battles (mostly military professionals).

2. Training personnel in combat techniques, logistics and command and control (military professionals).
3. Prediction of possible different outcomes of historical battles and campaigns, and hence the study of military strategies (and mistakes) from the past (military professionals, amateur war gamers and other military history authorities).
4. To study history by studying the assembled research data, without actually playing a war game (mostly history scholars and military history enthusiasts).

The focus of this book is on the last two categories (above): specifically using the techniques and methodology of military simulation to study in detail the first six months of the largest and costliest military campaign in history, namely Operation Barbarossa.

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2) The Power of Military Simulations in the Study of Military History

War gaming, in relation to the study of military history, is essentially the creation of an account of a historical event in simulation form. This begs the question: what specifically does a military simulation provide that a good history book, film or documentary does not?

While many are quite satisfied with reading a book or watching a film on a historical battle or campaign, a person who war games or simulates that same event is looking for something more. Specifically, he or she uses simulation to do a closer examination and analysis of all the aspects associated with the battle or campaign in question. Only a historical simulation frees the 'reader' from what James Dunnigan calls the 'linear' journey of a book or film in which it is impossible to realistically consider alternatives. In contrast, a military simulation is non-linear, much like the event itself. This means a person can wander through the event, changing variables if desired and still be in context. Anything less is little more than following someone else's historical understanding of a battle or campaign.

Whether looking for alternative historical perspectives, looking for the future in the past, validating new techniques through historical models or simply wanting to do some professional development, there is no more powerful, practical and useful analytical device than a historical simulation.

It has to be said that many detractors of the use of military simulation to predict historical outcomes, start with emotionally based views: that "war should not and cannot be reduced to numerical analysis". The idea is that using a purely quantitative analysis somehow belittles the immense human cost of war. In actuality however, the opposite becomes true: anyone playing a realistic military simulation becomes only too aware of the human cost. Emotions aside, the only serious argument put forward by the detractors is that it is impossible to predict unforeseen events, and this is why mathematical simulation or war gaming cannot predict an outcome. Logically this is true, but in practice it comes down to a matter of degree. The key words here should be 'cannot predict an outcome with certainty'. This is the key. Of course no one can ever predict an outcome with certainty, and we can only hope to assess the probability of a particular outcome.

There are however two areas where the detractors' main argument becomes particularly weak, or at least confused.

1. **There is a massive difference between using mathematical models to predict the future with many uncertain variables, and using mathematical models to predict a probable short-term outcome due to changing one significant variable in the past** .

   If the same data analysis, mathematics and computing power used by the professional military is applied to military history, then the probability of predicting a particular historical outcome for a given battle or campaign is much higher than forecasting a future battle. The reason for this is that many of the more unpredictable variables are fixed in the equations, or at least limited to a smaller range. These variables include: one side's more inaccurate intelligence, the weather, changes in political climate, production and manufacturing, receiving new weapons, mobilisation of resources, research and development of

new weapons, sudden removal of key personnel (e.g. someone had an unforeseen accident) and other sudden major developments. Many of these variables could not be easily predicted before the battle or campaign started, but become known or ‘fixed’ variables after the event (i.e. fixed by validated historical research). By changing one significant variable in the historical scenario, we can then examine the most probable alternative (short term) historical outcome: note the emphasis here is ‘most probable’ and not ‘certain’ outcome.

For example, a war game played before Operation Barbarossa would have a massive numbers of unknowns relating to virtually every facet of the campaign. However, a war game played today could contain every piece of available historical data to verify if the model (using all historical command decisions) followed the historical events and timeline. By changing one variable, such as not delaying an advance on Moscow by Army Group Centre in August 1941, the most probable alternative outcome can be realistically examined. [13] It must be carefully noted here that the probability of predicting a particular outcome diminishes as a function of the length of time between the ‘changed event or variable’ and the ‘predicted outcome’. Thus using our example above, if Army Group Centre had advanced on Moscow in August 1941, we can accurately predict the most likely outcome in October-November 1941, but less so an outcome in December 1941-January 1942. In other words: the probability that the Wehrmacht would have captured Moscow in the period September-November 1941 can be established with a high degree of certainty, but the probability that they could have held Moscow during the Soviet winter counter-offensive is less certain.

Purists in system theory (those who would usually support the use of military simulations) would maintain that changing one variable can change other variables in unpredictable ways. However the same purists have to look at the mathematics of the model, the variable to be changed and system theory in general, to admit we are talking about the “99 percent solution”. That is the probability of the new outcome occurring. The proviso is that the historical research is done and

carefully analysed. This is in fact the hard part (much more difficult than the simulation itself), and is what the bulk of this work contains.

2. **There is a complete difference between the 'failure of intelligence' and the 'failure of a military simulation to predict an outcome'.** The two are often confused. A dramatic failure of one side's intelligence will always result in unforeseen events regardless of how the outcome of a battle or campaign is predicted. In addition, very inaccurate intelligence is one of the unpredictable variables effectively eliminated by research in historical scenarios.

   A classic example of this is the use of the atomic bomb on Japan in 1945. Up to 5th August 1945, the Japanese military planners (including officers conducting war games in the Japanese High Command) assessed that they could put up a stout defence and inflict very heavy casualties on any force invading the Japanese home islands. They would have put all their available intelligence information into their model, and this information only changed after the atomic bomb was used. On 6th August 1945, the Japanese's worst fears were fully realised at Hiroshima. It has been put to me that this sequence of events is as an example of why mathematical simulation, or war gaming, cannot predict an outcome due to an unforeseen event: specifically the failure of Japan's war planners in July-August 1945 to factor in the atomic bomb! However this is <u>not</u> a failure of the Japanese war planners or their military simulation, but of intelligence. An even greater failure of Japanese intelligence was their failure to foresee the Soviet declaration of war and invasion of Manchukuo (Manchuria) on 9th August 1945. Obviously no prediction will be accurate if the data going into the predictive model is wrong or incomplete.

   Much more interesting than the Japanese High Command's position in July-August 1945 is that of the US at this time. The US did a similar war game assessment of a full scale invasion of the Japanese home islands using all the data available to them from the Pacific War. These operations (part of Operation Downfall) were codenamed Operation Olympic and Coronet, and were scheduled for 1st November 1945 and

1st March 1946. US planners assessed that these operations would cost the US approximately 80 000 killed and 290 000 wounded. [14] The US of course had an alternative to invasion in their war game analysis: the atomic bomb was successfully tested in July 1945, and they also knew the Soviets would be attacking the largest remaining Japanese army in Manchukuo in August 1945. In other words the US model simply had more accurate intelligence while the level of military simulation (war gaming) used was almost the same. Today, more sophisticated military simulations still indicate the US would have sustained at least 200 000 casualties (killed, wounded and missing) by invading Japan in late 1945.

Ironically, it is only when Operation Downfall is ‘war gamed’ by the student of the Pacific War, that the magnitude of the task facing the Allies in August 1945 really becomes apparent. Far from somehow belittling the human cost of war, such a war game only serves to illustrate the difficult moral decision facing President Truman in July-August 1945.

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If military history is the "professional officer’s laboratory of war", then the historical simulation is a critical means for experimentation. [15] No other medium of historical study allows one to manipulate almost any element of a battle, campaign or war, and then test the outcome with the same expectation of historical accuracy. By manipulating the key elements and operational decisions of a historical battle or campaign through simulation, a person gains a better understanding of how all aspects of the battle or campaign interacted. Moreover, it provides a unique opportunity to explore alternative strategies and tactics. Many war gamers do not ‘game’ at all. They simply study and manipulate the simulation by themselves. However there are always at least two sides in a military conflict, with each attempting to impose its will on the other. With both sides exercising free will, the number of ‘what ifs?’ to explore grows considerably. By comparison, when was the last time you explored the ‘what if?’ aspect of a historical battle through a book or a film?

For understanding and applying the historical lessons of war, or exploring realistic 'what if?' scenarios in military history as derived from a quantitative historical analysis, the historical military simulation will continue to be the most powerful tool available.

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3) The Difference between Qualitative and Quantitative Analyses

Another way to think of military simulations (or war gaming) is as a methodology or process, leading to a more disciplined analysis. I like to think of it as a quantitative process or methodology as opposed to a qualitative, or equally dangerous, a partially qualitative methodology. I use the term dangerous because when the latter is coupled with a political agenda or bias, it is usually useless and misleading as a study of the historical event. Of course there are many valuable qualitative documents with objective views, but one has to find (and validate) them.

In the qualitative process, an author is able to substitute numbers with adjectives, ignore whole areas of unsupportive data, and draw 'conclusions' that are firmly stated with no real proof or even analysis behind them. The adjectives and phrases used may include: "many tanks destroyed", "heavy casualties", "stiff resistance", "decisive victory", and "overwhelming odds", to quote some of my favourites. Unfortunately "many tanks" can be 3 to 300, and the others could mean almost anything. The author is allowed to get away with sloppy research and even sloppier thinking. The result is often ambiguous at best and outright propaganda at worst.

The partially qualitative process or document is even more potentially dangerous. In this case the qualitative analysis is usually presented with carefully selected quantitative data in the form of statistics, to support it. The analysis is presented as a quantitative analysis based on a historical research, but in fact this is an illusion. This is the classic example of "there are lies, damn lies and statistics", and is why most people are wary of statistics. The most common technique in relation to WWII statistics is to use them out of context, because it is usually difficult and self-defeating to

manipulate the figures directly (except for most Soviet era accounts, but then the Soviets had their own set of post-war rules). In other words, it is what is left out of the quantitative data that is important.

For example, one side's loss figures for a particular battle or campaign are not very informative (and often misleading) unless contextual statistics are included such as: overall strengths for both sides, enemy losses, and the time period being considered. A partially qualitative statement about a military campaign may include "force x suffered huge casualties in this period, over 100 000 in one year alone". Thus 100 000 casualties sounds unbearable in this context (i.e. a possible defeat for force x). However if force x had an average strength of 1 000 000 personnel over the year, only 10 000 of force x's casualties actually died, force y (the opposing force) had an average strength of 2 000 000 personnel over the year, and force y suffered 500 000 casualties, then the context and reader's perception of the campaign are very different. In proper context we find that force x's casualties represented only around 10% of the forces present over a whole year, only 1% of personnel present suffered fatal injuries, and 5 times as many casualties were inflicted on an enemy who had an average 2 to 1 numerical superiority (i.e. a possible victory for force x, and almost certainly a much higher Relative Overall Combat Proficiency (ROCP)). [16]

Leaving out pertinent statistics also allows the author the 'defence' that he or she was unaware of the 'new' data. My favourite description relating to such documents, books and films is "they are full of what's not in them". An author can present a detailed analysis of one aspect of the campaign with selected supporting data, and simultaneously treat another equally or even more important aspect of the campaign with a purely qualitative analysis. Apart from the occasional digression to discuss some 'selected hard facts', the partially qualitative process allows the same level of descriptive language and fanciful thinking. The vast majority of books written about WWI and WWII are fundamentally a qualitative analysis or partially qualitative analysis of the events in question. The skill of the reader is to sift any 'gold' out of the analysis, if there is any, usually by validating the data with as many other sources as possible.

It is far more uncommon to find a true quantitative analysis with a political agenda or bias because the author needs a lot more skill to present the data in the form which will support their argument, without simultaneously giving the reader the 'ammunition' to present an alternative argument. This is in essence the start of a true quantitative analysis and the war gaming process. Obviously our ideal is the quantitative analysis which makes a genuine effort to use accurate historical data to draw realistic and reasonable conclusions.

The first and most important step in any historical simulation is therefore the research, analysis and organization of the data involved. The architect of the simulation must attempt to at least start a genuine quantitative analysis. The data will then serve as the foundation of the simulation model. The quantitative analysis of this information is no small feat and for Operation Barbarossa, the largest military campaign in history, there will always be gaps and the analysis will never end.

The following are the principal reasons why using a historical simulation methodology leads to a more disciplined analytical process, and ultimately closer to a true quantitative analysis of any battle or campaign.

1. **The military simulation designer is forced to analyse aspects of the battle or campaign they may not wish to analyse for a variety of reasons.** These reasons may include: it is boring, not normally the main focus of their historical interest, too emotionally painful or doesn't fit their preconceived ideas. The historical simulation methodology requires as many aspects of the campaign to be simulated as practical because in many cases apparently obscure factors had a much greater impact on historical events, and command decisions, then readily apparent in a qualitative analysis.

   The rather dull, but vital, subject of battlefield logistics is very good example of a subject area most often inadequately addressed in the majority of current WWII history books. Almost invariably, battlefield logistics is cursorily treated and supposedly covered with phrases such as "force x was mostly dependent on horse drawn transport" or "force x had insufficient motor vehicles and relied on commandeered civilian

vehicles”. Such phrases are completely subjective and no effort is made to analyse in depth the true relative logistical situation for each of the belligerents. A historical simulation methodology requires an analysis of all aspects of battlefield logistics if at all practical, including: numbers and types of transport vehicles available (including horse, motor vehicle, air and rail), terrain, weather, the quality and quantity of transport infrastructure present (roads, rail, ports and airfields), total supply lift, effective supply radius and the type and number of combat units being supplied (i.e. supply demand, which varies tremendously for different types of combat unit).

2. **The military simulation designer is forced to attempt to quantify everything, whether it be a physical parameter like geography and weather, or a less tangible parameter like leadership or combat skill.** This is possibly the most powerful aspect of the historical simulation methodology. The simulation architect is simply not allowed to ignore, guess, or use careless thinking on any aspect of the simulation. This is because the simulation represents the real world and real issues, and will ultimately be tested against real world results.

   For example, it’s no good estimating combat proficiency or skill based on the ‘knowledge’ that your country produced brave soldiers. Bravery and motivation did not automatically translate into higher Relative Overall Combat Proficiency (ROCP). The questions raised include: How effective were the command, control and communication systems? How well did different land and air combat units cooperate together at the tactical and operational level? How thorough was the training, especially for officers and NCOs? What was the prevailing culture and what were the reasons for going to war (motivation)? What was the kill-loss ratio achieved in combat? These questions then raise other questions which the simulation designer may not have even initially thought of. In the end the designer has to put a value on all these parameters, and justify them. Of course it is impossible to answer every question with a suitable answer, but if all assumptions are stated, the designer exposes the weakness and strength of their arguments for others to use, agree with or change.

3. **The military simulation designer is forced to repeat the process (above) for all sides.** In other words, an analysis is never formulated in a 'vacuum', and is always considered relative to the other side and the time period in question.

   This is one of my pet hates in the qualitative analysis. Authors will often repeatedly elaborate on an aspect of one side which resulted in a weaker performance, when the only thing that really matters is: what was the magnitude of the aspect <u>relative</u> to the other side at the time? One of the most glaring examples of this, in many accounts of Operation Barbarossa, is the debate on logistics. There are endless diatribes about the poor logistical support in the German Army compared to the Western Allied Armies, their dependence on horse transport, and the apparent effect on the campaign in the East. If any quantitative analysis is involved, it usually focuses entirely on the number of horses and trucks involved in the invading Wehrmacht forces. Yet the only number that really matters is the Wehrmacht's Supply Distribution Efficiency (SDE) relative to the Soviet SDE in 1941, <u>and not relative</u> to the fully motorised US and British Armies that landed in France in 1944, or the armies of today. Most current works on Operation Barbarossa (especially those highlighting the invading force's logistical weaknesses) completely ignore the Red Army's Supply Distribution Efficiency in 1941.

4. **The military simulation designer has a means of calibrating and testing the analysis.**

   As stated above, the simulation accuracy can be tested against real world historical results. Ideally the simulation represents a snapshot of a historical place and time, with the physical and cultural world simulated. If all key decisions are the same, then a valid simulation's outcome will probably follow the historical result. The stress here is 'probably' because no two complex events will be exactly the same and there were many examples of incredible combat results which were not predictable. However the larger the simulation, the longer the timeline and the more times the simulation is run, then the closer the results will get to the actual historical outcome. If the simulation has

significant unrealistic parameters then the consistent deviation from historical results is usually soon observed. No one can say any book or film can be ‘calibrated’ for realism.

5. **The military simulation designer, or end user, can easily improve the simulation**.

   If the end user disagrees with any aspects of the designer’s (or author’s) quantitative analysis, or additional or new historical data becomes available, he or she can improve and build on the simulation. The methodology adopted above makes this relatively easy because the simulation designer has had to quantify each parameter, and had to justify the assumptions and conclusions made about each parameter. In effect, the simulation designer has already initiated debate by exposing many of the weaknesses in the simulation to possible alternative arguments.

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4) Tactical, Tactical-Operational, Operational and Strategic Military Simulations

Military simulations, or war games, are normally categorised as tactical, tactical-operational, operational or strategic. The predominant feature that decides how a war game is categorised is the space and time scale used by the units involved in the simulation. The concepts and terms (definitions) used in the following discussions, are based on military applications in the first half of the 20th Century. It should be noted that some of these concepts and terms used vary slightly if applied to military history and organisations in the 19th or late 20th Century. [17]

a. Tactical Level Simulations

Tactical level simulations, or war games, have space scales ranging from 40 to 150 meters per hex, and times per turn ranging from 2 to 6 minutes. Tactical war games are concerned with the tactics related to moving and fighting small combat units over a limited timeframe (usually a few hours), and in small areas.

Small combat units are: squads, sections, individual artillery pieces and individual AFVs. In tactical games each turn includes time for movement and combat. Combat involves mostly ‘line of sight’ calculations, where opposing forces shoot at what they can see from particular terrain features. Indirect fire is used for short rang weapons such as mortars, and abstractly simulated for off map heavier weapons. The combat models used are usually extremely detailed, although not always that realistic. They include individual weapon characteristics, AFV characteristics (such as armour thickness, slope, shape and facing), rate of fire, target ranges, all terrain features (including elevation and depression), and a multitude of other factors. In addition, an assessment of the tactical combat proficiency for each side is included. [18]

Some very good tactical level military simulations with realistic combat models are: Squad Leader and Advanced Squad Leader [19] , Panzer [20] , Steel Panthers [21] and Tigers on the Prowl. [22]

b. Tactical-Operational Level Simulations

Tactical-operational simulations have space scales ranging from 150 to 300 meters per hex, and times per turn ranging from 6 to 12 minutes. Tactical-operational war games fill a gap between tactical and operational games. Many war gamers would call these tactical games because the manoeuvre units are normally platoon size and the thinking behind the deployment of such units is tactical in nature. In addition, these simulations are also concerned with the tactics related to moving and fighting ‘small combat units’ over a limited timeframe and in relatively small areas. However ‘small combat units’ are now platoon size infantry or tank units, and artillery batteries.

In tactical-operational war games, each turn includes time for movement, combat and limited ‘operational type’ activities. Operational type activities may include: immediate ammunition and fuel replenishment, coordination of attacks between different companies, battalions and even divisions (on very large scenarios), and fatigue and disruption recovery using higher headquarters. Combat still involves mostly ‘line of sight’ calculations from particular terrain features. Indirect fire is more developed,

with short and long range weapons (artillery) on the map. The combat resolution models used are usually detailed, although in most tactical-operational war games the combat model is less involved and less realistic than the smaller scale tactical war games.

If possible, a well-designed tactical-operational simulation should include all the combat resolution model details found in purely tactical simulations. If it is not possible to include the combat model detail directly, then a 'weighting factor' should be included to simulate the detail parameter. This does make the design of tactical-operational war games more challenging. For example, in a good tactical level simulation, tank armour protection over different parts of a tank is simulated. However in many tactical-operational war games only the strongest part of the tank (the frontal armour) is usually used in calculating the defensive (armour) strength of the tank platoon. This is because it is generally assumed that the portion of the tank platoon engaging the enemy would always manoeuvre to face the enemy. But, it is simultaneously unrealistic to assume that the entire tank platoon would always face in one direction at the same time, or that certain types of weapons (e.g. aircraft and artillery) would normally hit the tanks frontally. Thus if there is no weighting factors to compensate for non-frontal hits on the tanks in the platoon, then outlandish and unrealistic results will occur. This is because the majority of tanks in WWII were actually destroyed by non-frontal hits, and if there is no weighting factor to represent this then certain types of tank become much stronger in the simulation than they were historically. [23]

In addition to more complex combat resolution models, tactical-operational simulations need to establish the tactical combat proficiency for larger combat units: this is now much more critical, and has far more impact, than in smaller tactical simulations. For example, in tactical level simulations the tactical combat proficiency of individual tanks is considered, which includes factors for the ergonomics of the tank's crew and average crew training. But in tactical-operational simulations, the tactical combat proficiency of individual tanks as well as how well the tanks in the platoon worked together and with accompanying infantry, needs to be considered. This difference in tactical-operational level combat proficiency was critical in tank combat: factors such as the presence of

radios in the tanks, and the training and combat doctrine of the tank platoon as whole, made a huge difference to historical combat outcomes.

The above are just two examples of why military simulation design becomes progressively more challenging as you move up the scale. Some examples of good published tactical-operational simulations, with reasonable combat resolution models, are: Steel Panthers III [24] , Eastern Front II [25] , West Front [26] , Battleground Ardennes [27] , Across the Rhine [28] , PanzerBlitz [29] , and Panzer Leader [30]

c. Operational Level Simulations

Operational level simulations have space scales ranging from 500 meters to 30km per hex, and times per turn ranging from 2 hours to 2 weeks. A good description of the 'operational level' is "a view of the battlefield on a scale just exceeding that at which differing ranges of various direct fire weapons are significant". [31] Operational level simulations cover the widest range of space and time scales: as such they are the most challenging and complex to 'play', and the most difficult to design well.

I'm sure many tactical level aficionados and 'Advanced Squad Leader' players would dispute this statement! However, the fact is that most tactical simulation rules are related to the application of the laws of physics to combat (which can itself be very complex), with more limited rules relating to human behaviour and logistics. A good operational simulation has to simulate all the factors at the tactical level, and simultaneously all the operational factors at all other levels: the simulation designer and player are forced to think about multiple, wide ranging problems simultaneously, and how they will interact. Operational level simulations are concerned with the tactics related to moving and fighting small and large combat units, over a large timeframe and in large areas. Moreover, combat units range from company size to entire divisions, and the thinking behind the deployment of such units is simultaneously tactical and operational.

In well-designed operational level simulations, each turn includes time for movement, combat and all 'operational' type activities. Operational activities should include all the following:

1. Decision making in regards to the geographic and military objectives of the battle or campaign.

2. Interpretation of intelligence and likely enemy deployments.

3. Formulating a plan and deploying suitable units to achieve the objectives, taking into account: terrain, available forces, available logistics, known tactical and operational combat proficiencies (the latter includes unit cooperation, and overall command and control), weather forecasts, and likely enemy actions.

4. Planning the long term ‘health’ and readiness of all combat and non-combat units. This includes supply of the unit, fatigue effects, receiving replacements, and even training in long campaigns.

5. Transport and supply logistics such as: moving units by rail or road to the combat sector, deployment of ‘marching’ units, supply stockpiling, organising the supply lines and the continuous resupplying of units.

6. Organising rear area security. This includes protection of supply lines, and supply and support infrastructure (e.g. bridges, railroads, ports etc), against enemy interdiction.

Combat resolution in operational level simulations, generally involves calculations based on the ‘strengths’ of the units involved, taking into account: terrain, weather, unit entrenchment (fortifications), and unit posture (i.e. defensive or attacking). The ‘strength’ of each unit is calculated based on the unit’s TOE, actual equipment and personnel present, readiness, and tactical and operational combat proficiency. Indirect fire should be fully simulated with most weapons deployed on the map, and each side’s historical artillery command and control systems in place. The same applies to aircraft ground support and interdiction operations.

Well designed operational simulations should include as many of the combat model details found in tactical-operational war games, as possible. Obviously it is not usually possible to include the detail directly, so weighting factors have to be included to simulate the detail parameter. This is where operational level simulations take a quantum leap in complexity of design over tactical simulations: it is also where many operational level

‘war games’ start to depart from reality. If a simulation designer is looking to maintain realism in the operational level simulation, at least to the level of a good tactical-operational simulation, the main problem areas to be overcome are as follows:

1. Incorrect balance between the space scale and time scale of the simulation. [32]
2. Incorrect use of Zone of Control (ZOC) effects, and incorrect force density or frontage. [33]
3. Using the equipment and personnel historically available in each unit, and NOT its TOE: i.e. using the combat unit’s actual strength and not its authorised strength.
4. Using the correct attack and defence factors for equipment and personnel resources in the unit, to accurately calculate its correct maximum overall attack and defence strength. [34]
5. Including air combat units that are fully integrated into the overall combat model, and with the ability to fulfil conditions 3 and 4 above. [35]
6. Using an accurate measure of the tactical and operational combat proficiency for each side, including historically accurate command and control systems. [36]
7. Developing a realistic series of Combat Results Tables (CRTs) for manual map based simulations, or using realistic algorithms for combat resolution in computer based simulations. [37]

As a rule the combat algorithms (item 7 above) used in calculating combat results have been carefully worked out in most current operational level war games, not least by the military themselves. However the historical research needed for items 3-6 (above) is often superficial or missing altogether. In addition, items 1 and 2 (above) are often poorly designed and thought out in many operational level war games, leading to predictable outcomes which are more attributable to the simulation’s mechanics than any command decisions made by the ‘players’. [38] Coupled

with the need to simulate all operational activities, it is easy to see why these war games are the most challenging to design, and why realism is often sacrificed for 'playability'.

A few operational level 'systems' utilise a full equipment and resource database, (including aircraft). This enables these systems to fully address items 4, 5 and therefore 3, in the above list of problem areas: computational methods and the power of modern computers mean that even at the operational level, the life cycle of individual weapons, vehicles and infantry squads can be tracked and used in combat resolution. Despite the millions of calculations involved, these systems repeat this process for each game turn, tracking how each individual combat unit losses or gains resources.

Operational level systems utilising a full equipment and resource database, have huge advantages in achieving realism compared to other similar types of system. These advantages include:

1. The exact maximum attack and defence strength of the manoeuvre unit (combat unit) can be calculated, based on the individual tactical attack and defence values of the individual resources actually in the unit. This enables most of the combat model details found in tactical war games to be directly included in the operational level combat model, without having to use abstract weighting factors. Systems without a full equipment and resource database have to use a fixed maximum strength value for each unit, set by abstract calculations by the game or scenario designer. The player has to hope the designer is using the correct TOE, actual equipment and tactical rating of the equipment, because it cannot be verified within the simulation's parameters.

2. It allows mixed equipment in the manoeuvre unit. Therefore the unit is not rigidly classified as a 'hard' (armoured) target, or a 'soft' (none armoured) target, but a mixture of both. This also applies to air units with fighters, bombers, reconnaissance and ground attack aircraft.

3. The exact attack and defence strengths of each manoeuvre unit is calculated for each turn as the individual resources within the unit change. The unit may effectively become more 'hard' (if it losses infantry or gains tanks) or more 'soft' (if it losses tanks or gains

infantry). This means the type of weapons lost by combat or attrition, or gained from replacements, is included in the combat unit's strength change each turn. Other systems can calculate changes in strength only as a percentage of the full strength and then reduce or increase this over time. [39]

4. It allows much higher resolution of changes in overall manoeuvre unit strength. Thus if an entire division losses only 1 infantry squad (around 10 men) then even this is registered as a microscopic reduction in the unit's (division's) overall strength. Other systems have varying degrees of resolution in unit strength ranging from 3 to 4 steps in board games (which is very understandable), to 1% point of the unit's maximum strength.

5. It enables air combat units to be properly integrated into the land model, and for them to meet conditions 1 - 4 (above). Most other operational level simulations still have to treat air to air combat and air to ground combat in an abstract fashion, often using 'off map' units. Designers and players cannot therefore verify the air strengths of individual air combat units within the simulation's parameters.

6. It enables new equipment types to be issued to air and ground units in the course of the campaign, with the resultant changes to unit strength accurately calculated. Other operational level simulations simply cannot simulate this directly: they have to utilise more abstract means to simulate new equipment introduction, which is again difficult to validate within the simulation's parameters.

Some of the better published operational level war game systems, with good to reasonable combat models and good operational level control, are: The Operational Art of War (TOAW) [40] , War in the East [41] , Decisive Battles of WWII [42] , Panzer Campaigns series [43] , V For Victory Series [44] , World at War series [45] , War in the Pacific [46] , and Army Group North, Centre and South. [47] Notably, of the aforementioned list only 'The Operational Art of War', 'War in the East' and 'War in the Pacific' have a comprehensive equipment and resource database. Other important combat model parameters and operational activities are simulated by different games in a variety of ways. For example, the 'V For Victory Series' and

‘World at War series’ are excellent at simulating the periodic nature of supply, and command and control, at the operational level. [48]

Finally it has to be said that the large Army Group North, Centre and South series, is probably the most realistic manual (map based) simulation of operation Barbarossa available. By using a unique sequence of play, which is different for the German and Soviet player, the game system attempts to provide a proper simulation of the differences between the two sides at the operational level in 1941. This is something that many other operational level simulations struggle to do, and is quite an achievement in this age of computers. Apart from some excellent features in TOAW, most current operational level simulations do not separate tactical level and operational level combat proficiency, but group them together as ‘overall combat proficiency’. The result is that ‘operational level combat proficiency’ is often poorly and inaccurately simulated (if at all). [49]

d. Strategic Level Simulations

Strategic level simulations have space scales ranging from 31 to 100km per hex, and times per turn ranging from 1 week to 3 months. Strategic simulations rarely focus on one front or campaign, but usually the conduct of a war as a whole.

The combat aspect of strategic level simulations is concerned with the strategy related to moving and fighting very large units over a large timeframe in very large areas. Manoeuvre units are normally corps units with 3-6 divisions per corps. At this scale realism in the combat and operational model is not the predominant objective. Most of the operational decision making, painfully thought out at the operational level, has been done by the divisional, corps and army commanders. Strategic simulations abstractly simulate most operational issues such as: command and control, unit cooperation, small area geographic objectives such as crossing rivers, tactical and operational combat proficiencies, the ‘health’ and readiness of individual units, and transport and supply logistics.

A good strategic simulation should still simulate the dominant factors at the operational level, namely: overall supply, replacements, overall combat

proficiency, weather, terrain, and the integration of land, air and sea forces. The good design habits for operational level simulations still apply, particularly those related to: the balance between the space scale and time scale of the game, ZOC effects and force density or frontages, and developing realistic Combat Results Tables (CRTs) or realistic algorithms for combat resolution. At the same time the Strategic level simulation has to address strategic issues facing the country.

In well designed strategic level simulations, each turn includes time for movement, combat, supply etc, which are all operational activities, as well as more 'strategic activities'. Strategic activities should include all the following:-

1. Decision making as regards to the political and geographic objectives of the war.
2. Formulating a strategic plan and ensuring suitable units are going to be available to achieve the strategic objectives using military action, i.e. we are not interested in diplomacy and trade agreements here!
3. Implementing all aspects of strategic warfare such as strategic bombing and submarine warfare.
4. Mobilisation of the country's war economy. This includes: recruitment and training of new military personnel, war production, and management of energy and raw material resources.
5. Research and development of new weapons, and selection of weapon production to support the strategic plan. For example, it is not a good idea to increase submarine production if you've just launched a land invasion of the Soviet Union (as someone did)!

Some good strategic level simulation systems, with reasonable combat models are: World in Flames [50] , Advanced third Reich [51] and The Operational Art of War. The latter can go up to 50km per hex as a system and obviously enables all the operational level aspects to be simulated. However as the system is entirely operational in its focus, it struggles to address the strategic activities (above).

Probably the finest strategic manual (map based) simulation of WWII available is 'World in Flames' (WIF). The full simulation includes 7 maps, 6 000 counters and a 122 page rule book with additional designer and scenario notes! WIF manages to simulate most of the dominant operational issues facing land armies in WWII, and includes a fully integrated land, air and sea combat model. The naval and naval-air combat models (and hence the war in the Pacific), is particularly realistic for a strategy game. The main focus of the simulation is however strategic and full attention is paid to all the strategic activities detailed above.

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[2] J. Dunnigan, The Complete War Games Handbook, William Morrow and Company, New York, 1992, p.146.

[3] Modern military simulations show that anyone 'playing' a campaign on the Eastern Front during WWII will find they suffer far more casualties if they stubbornly remain on the defence. The dictates and complexities of a modern mechanised war in open terrain mean the defensive force suffers disadvantages which often result in higher overall losses. For example, the defensive force is far more subject to massive operational losses, which are losses not resulting from direct combat. This is because defensive forces are more subject to encirclement by the opposing mobile forces (which generally also maintain the initiative). In addition, temporary losses due to breakdowns, unserviceable equipment etc, are far more likely to become total losses due to capture by the attacking (and hence advancing) enemy.

[4] J. Dunnigan, The Complete War Games Handbook, William Morrow and Company, New York, 1992, p.146.

[5] L. Hart, History of the First World War, Papermac-Macmillan Publishers Ltd, London, 1997, pp. 29-30.

[6] R.H. S. Stolfi, Hitler's Panzers East, University of Oklahoma Press, Norman, 1991, p. 84.

[7] J. Erickson, The Road to Stalingrad, Phoenix-Orion Books Ltd, London, 1998, p. 7. Also, H. Boog, et al. (German Research Institute for Military History at Potsdam), Germany and the Second World War, Volume IV: The Attack on the Soviet Union. Oxford University Press, New York, 1996, p. 275.

[8] H. Boog, et al. (German Research Institute for Military History at Potsdam), Germany and the Second World War, Volume IV: The Attack on the Soviet Union. Oxford University Press, New York, 1996, pp. 257-276.

[9] R.H. S. Stolfi, Hitler's Panzers East, University of Oklahoma Press, Norman, 1991, pp. 85 and 86. Refer to Volume VI, chapter titled 'Historical and Current Results of War Gaming Operation Barbarossa' for discussion of the results of the German pre-Barbarossa war games. In brief, the outcome of these tests indicated the bulk of the Soviet Western Front could be destroyed west of the Dnepr River (as occurred historically), and they do not generally support the view in some quarters that Operation Barbarossa was fundamentally flawed by inadequate logistical planning.

[10] J. Dunnigan, The Complete War Games Handbook, William Morrow and Company, New York, 1992, pp. 234-235.

[11] J. Erickson, The Road to Stalingrad, Phoenix-Orion Books Ltd, London, 1998, pp. 8 and 9.

[12] J. Dunnigan, The Complete War Games Handbook, William Morrow and Company, New York, 1992, p. 236.

[13] Refer to Volume VI. for more on current results of war gaming Operation Barbarossa.

[14] J. F. Dunnigan, A.A. Nofi, The Pacific War Encyclopedia, Checkmark Books-Facts on File Inc, New York, 1998, pp. 317-320. Operation Olympic involved the invasion of Kyushu, and it was estimated the US would sustain around 31 000 killed and 94 000 wounded. Operation Coronet involved the invasion of Honshu, and it was estimated the US would sustain around 49 000 killed and 196 000 wounded.

[15] The Evolution of Modern Warfare: Book of Readings, Department of the Army, US Army Command and General Staff College (USACGSC), C610, Fort Leavenworth, April 1991, Preface.

[16] Refer to Volume V – for details on factors related to Relative Overall Combat Proficiency (ROCP).

[17] Refer to Volume VI, chapter titled 'Military Simulation Concepts and Definitions', especially in relation to war gaming Operation Barbarossa.

[18] Refer to Volume V – for details on assessing Relative Overall Combat Proficiency (ROCP), at the tactical level, in the Soviet and Axis Forces from 1941 to 1945.

[19] Multi-Man Publishing, MMP. (For Avalon Hill). Many rules: ASL is probably the most advanced tactical level war game ever made, and has achieved more sales than any other board (map) based war game.

[20] Excalibur Games.

[21] Strategic Simulations Inc, SSI.

[22] HPS Simulations.

[23] Refer to Volume I, Part II, 2. 3) e. - ' Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating a Land Based, Motorised Mobile Fighting Machine's (MFM's) Overall Combat Power Coefficient (OCPC) - Shape and Size Factor (SSF)), for details on suitable weighting factors relating to AFV armour facings.

[24] Strategic Simulations Inc, SSI.

[25] Talonsoft, Campaign Series.

[26] Talonsoft, Campaign Series.

[27] Talonsoft.

[28] MicroProse Software Inc.

[29] Avalon Hill Game Company, Old 1970s board game, still good with modified rules. Few operational elements

[30] Avalon Hill Game Company, Old 1974 board game, also still pretty good. Few operational elements.

[31] The Operational Art of War, Century of Warfare User Manual, Talonsoft, 1998, p. 6.

[32] Refer to Volume VI, chapter on 'The Space and Time Question in Military Simulations', for details on this critical element of all military simulations.

[33] Ibid.

[34] Refer to Volume I, Part II – 'The Methodology Used for Analysing Weapon System Effectiveness, and the Structure of the 1941 Soviet and Axis Resource Database'.

[35] Refer to Volume IIB 5. – 'The Luftwaffe in 1941' for example.

[36] Refer to Volume V – for details on assessing Relative Overall Combat Proficiency (ROCP), at the tactical - operational level, in the Soviet and Axis Forces from 1941 to 1945.

[37] Refer to Volume VI, in relation to war gaming Operation Barbarossa.

[38] Refer to Volume VI, chapter on 'The Space and Time Question in Military Simulations' for more on this.

[39] For example, a Soviet 1941 tank brigade normally contains a tanks and infantry component. If the tank brigade lost all its tanks (which often happened in 1941-42) it would no longer realistically be a 'hard' armoured force. Operational level simulations without a full equipment and resource database would still classify the tank brigade as an armoured force at reduced strength, when in fact it was a soft (infantry) force at reduced strength. In real terms, the actual overall combat power of the two was very different.

[40] Matrix Games (Ex Talonsoft).

[41] 2 by 3 Games, Matrix Games.

[42] Strategic Studies Group (SSG), (Matrix Games). A series of simulations for various WWII campaigns.

[43] HPS.

[44] Three-Sixty Pacific Inc, C Atomic Games.

[45] Avalon Hill, Atomic Games.

[46] 2 by 3 Games, Matrix Games.

[47] GMT Games. Large, map based manual war games. They utilise a scale of 8km per map hex.

[48] Each side's commander has to plan ahead and think carefully about objectives and available supply. Supplies and HQ command and control functions are allocated to selected combat units, only once in every 24 hours.

[49] Refer to Refer to Volume V – on Relative Overall Combat Proficiency (ROCP). Details on the differences between 'tactical level' and 'operational level' combat proficiency are included, and how these are manifested in an armed force.

[50] Australian Design Group, ADG. WIF 6th Edition is probably the most detailed manual (map based) simulation of WWII available.

[51] The Avalon Hill Game Company.

2. The Integrated Land and Air Resource Model

The purpose of this chapter is twofold: firstly, to summaries what an 'integrated resource model' is and why it is essential to obtaining historical accuracy when analysing a large and complex military campaign, and secondly, to define the structure, concepts and terms used to build a complete mathematical model representing a country's war effort.

1) What is an Integrated Land and Air Resource Model (ILARM)?

The model principles described in this chapter are not concerned with the detail structure of the armed forces in question (this will come later), but are concerned with how we can model (or simulate) the creation and flow of personnel and equipment from mobilisation and manufacture, to loss from combat and attrition. For our purposes, this mass of personnel and equipment (vehicles, weapons and squads) will hence be termed 'resources'.

Therefore an Integrated Land and Air Resource Model can be defined as: **a complete mathematical model representing a country's war effort, which enables the creation and flow of all (war related) resources to be continuously tracked from mobilisation and manufacture, to loss from combat and attrition**.

Volume I Part II of this work, titled 'The Methodology Used for Analysing Weapon System Effectiveness, and the Structure of the 1941 Soviet and Axis Resource Database', focuses on determining what resources will be included in the model, and the relevant attributes relating to each type of resource. Part II analyses the physics of the vehicles, weapons and squad types (all types of resource) involved in the Integrated Land and Air Resource Model. It describes how the 'combat power' and 'specific combat attributes' of individual resource types are calculated.

a. The Underlying Principles

There are two fundamental principles that form the foundation of the Integrated Land and Air Resource Model, and to which the model must adhere at all times. These are:

The conservation of resources .

The ‘conservation of resources’ principle is similar to the ‘conservation of mass’ principle in physics. In this case the ‘mass’ is defined as the resources (personnel and equipment) involved. The conservation of resources principle dictates that resources cannot be created from nothing and they cannot disappear, unless destroyed or scrapped. This initially sounds obvious because the concept is simple. In fact adhering to the principle of conservation of resources is difficult to achieve in practice. It means that all personnel (initially available and newly mobilised), and all equipment (initially available, newly manufactured, and commandeered), has to be continually tracked within the model from manufacture and deployment to the end of its service life, or to the end of the period in question.

The model is an interactive ‘system’ .

The term ‘Integrated’ in the model title refers to the fact that the model is a complex interactive system. This means that any change in any part of the model (or system) has a direct cascade effect on many other model components.

For example, if fewer resources such as trucks are allocated as replacements to deployed combat units, then more trucks are available for newly mobilised units and support infrastructures. Improved support infrastructure results in a better overall Supply Distribution Efficiency (SDE). The net result is that older deployed units are less mobile, while new units are more mobile and all units get supplied more efficiently (higher SDE).

Another example is, if the Soviets lose even more divisions in June-July 1941 than was historically the case (in the Operation Barbarossa

simulation), then the massive influx of newly mobilised replacements will be diverted to newly mobilised divisions, making them stronger quicker. If the Soviets lose fewer divisions in June-July 1941 than was historically the case, then the divisions deployed on 22nd of June 1941 will have more time to get closer to their full strength, while the newly mobilised divisions will take longer to get to their full strength.

It goes without saying that without the power of modern computers, it would be almost impossible to create a practical integrated resource model of a county's war effort that conformed to the two principles above: even a military simulation of a relatively small battle would be difficult and largely impractical. There are two types of integrated resource model used in 'Operation Barbarossa: the Complete Organisational and Statistical Analysis'; namely the Fully Integrated Resource Model and the Partially Integrated Resource Model.

b. The Fully Integrated Land and Air Resource Model (FILARM)

In the FILARM model, all resources present at the start of the campaign, and all resources received from all sources during the campaign period, are modelled.

'Fully' refers to the fact that all resources, in all physical locations (i.e. all fronts) are included, and <u>not</u> only those on the Eastern Front (Axis) or Western Front (Soviet).

Obviously the countries of primary concern in Operation Barbarossa are Germany and the Soviet Union. For these countries Fully Integrated Land and Air Resource Models (FILARMs) are used. The FILARM model is also used if the bulk of a county's armed force was committed to support Operation Barbarossa in 1941. This includes all Finnish forces, the Hungarian Air Force and the Rumanian Air Force. The following table is a summary of the type of model employed in 'Operation Barbarossa: the Complete Organisational and Statistical Analysis' for each of the combatant's land, air and naval forces.

Model Type Employed for each of the Combatant's Land, Sea and Air Forces

	Land	Air	Sea
Soviet	FILARM	FILARM	F
German	FILARM	FILARM	P
Finnish	FILARM	FILARM	F
Slovakian	PILARM	PILARM	F^
Hungarian	PILARM	FILARM	N/A
Rumanian	PILARM	FILARM	F
Italian	PILARM	PILARM	N/A
Bulgarian	N/A*	N/A	F**

* N/A Not applicable, no significant forces committed
^ Part of German Danube Flotilla
** Part of Axis naval forces in Black Sea

Given that Operation Barbarossa was the largest invasion in history, leading to the largest and bloodiest military campaign ever recorded, I'm sure the reader will understand that creating Fully Integrated Land and Air Resource Models for the main belligerents is a massive undertaking. It is inevitable that some components of the respective FILARM models will need revising and updating as more accurate historical information becomes available. However, these updates will be relatively minor in the overall scheme of the ILARM models and the historical context. Today sufficient archival information is available to build accurate FILARM models for Operation Barbarossa, with all the key military, economic and environmental parameters included.

c. The Partially Integrated Land and Air Resource Model (PILARM)

In the PILARM model, all resources allocated to East Front forces present at the start of the campaign, and all resources received by forces on the East Front during the campaign period, are within the model.

'Partially' refers to the fact that only resources allocated to the East Front are included. The East Front in this case is defined as: forces entering the Soviet Union after 22nd of June 1941, or which were made available by the relevant command to enter after that date. Note, some minor Axis Allied forces were made available to the relevant commands in 1941, but did not actually enter the Soviet Union.

A Partially Integrated Land and Air Models (PILARM) is used for most of the Slovakian, Hungarian, Rumanian and Italian forces committed to support Operation Barbarossa in 1941 (refer to the table above). The Hungarian and Rumanian Air forces are the exceptions.

d. Naval Forces Involved in Operation Barbarossa

At this point it is necessary to mention the naval forces involved in Operation Barbarossa, and how they fit into the Integrated Land and Air Resource Models.

Although the naval forces were relatively small compared to other naval theatres in WWII, they were still significant and carried out some major operations. These were mainly evacuating or supplying port cities such as Odessa, Riga and Tallinn. The evacuation of Tallinn by the Soviet Baltic Red Banner Fleet was a particularly large naval operation in 1941. [52] The successful Soviet evacuations of Odessa and the Hango peninsula garrison in 1941 are also noteworthy naval operations. The only amphibious landing operation in the Baltic Sea in 1941, which could be considered large scale, was the German operation *Beowulf* . This involved the invasion of the Saaremaa (Osel) and Hiiumaa (Dago) islands in the Baltic, by the 61st Infantry Division and support units, from the 14th September to 21st October 1941. [53] The most significant amphibious landing operation in the Black Sea was the Soviet landings on the Kerch peninsula in late December 1941. [54]

The various combatant's naval forces are not 'fully integrated' into the Fully Integrated Land and Air Resource Model (FILARM). This is because the seagoing personnel, smaller pieces of equipment, and dockyard supply and repair infrastructures are not tracked in the naval models. Hence naval personnel and equipment should be seen as additional to those in the FILARM model, with the exception of naval personnel that became naval infantry and fought as ground troops, and all land based naval aircraft. The latter two <u>are all included</u> in the FILARM models. This is particularly significant for the Soviets because all aircraft in the Soviet VVS-SF (Northern Fleet), VVS-KBF (Red Banner Baltic Fleet) and VVS-ChF (Black Sea Fleet) are all included in the Soviet FILARM model. These were

all significant land based naval air forces, and were primarily involved in air to air and air to ground combat during Operation Barbarossa.

In fact the most significant naval contribution to the Soviet-German war in 1941 did not take the form of ships or naval operations at all. It was the 146 899 Soviet naval personnel that transferred to the Red Army in the form of naval infantry in the second half of 1941. [55] In all, over 500 000 Soviet naval personnel were transferred to the Red Army ground forces in WWII. In 1941-42 alone, 21 naval infantry and 30 naval rifle brigades went into the front lines against the Axis armies. The Soviet naval personnel transferred to the Red Army, and the formation of all naval infantry and naval rifle brigades in 1941, are included as land forces in the Soviet FILAM model.

Although the naval forces are not fully integrated into the FILARM and PILARM models, the waterborne components of all the naval and river forces (the vessels themselves) involved in Operation Barbarossa are included. Where the majority of a county's naval forces were available to support Operation Barbarossa then all that country's major warships are shown in the naval model. In this case the naval model is referred to as a Full (F) model. Where only a minor portion of a country's naval forces were available to support Operation Barbarossa then only the available ships are shown. This is referred to as a Partial (P) naval model (refer to the table above). The most powerful navy involved in Operation Barbarossa was the German Navy, but they committed relatively few forces to support Barbarossa because they were busy fighting the Royal Navy at the time. [56] Thus a Partial (P) model is used for the Kriegsmarine forces in the East during 1941.

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2) The Objectives of the Integrated Land and Air Resource Model

One may ask; "why is such a comprehensive model necessary"? The reasons are related to achieving historical accuracy and can be summarised by the following:

a. The Strategic Context of the Military Campaign: Bottlenecks in the Mobilisation Process

An Integrated Land and Air Resource Model **enables a full analysis of the belligerent's economic and logistical capabilities, as related to a specific military campaign and in the (strategic) context of their overall war effort**. In addition, it **enables bottlenecks in the war mobilisation process to be determined, and highlights the practical and logistical limits on the size of any operational field army**.

The Fully Integrated Land and Air Resource Model (FILARM) is essentially a study of the flow of manpower and different types of equipment, and how they merge together. As such it is possible for a country to strategically have too much of one resource and insufficient of another, resulting in the inability to produce combat and support units of a certain type. The following examples serve to demonstrate some 'bottlenecks' in the various mobilisation processes during Operation Barbarossa, and why a Fully Integrated Resource Model is needed to accurately determine the extent of these bottlenecks.

The Soviets may have actually over-mobilised in 1941. Between 22nd June and the 31st December 1941, the Soviets called up 5 500 000 reservists and conscripts into active service. In addition another 4 000 000 men and women 'volunteered' for militia or volunteer units, and most of these ended up in the Red Army. [57] Unfortunately, approximately 500 000 reservists were apparently taken prisoner before being taken on strength. [58] With this almost unlimited supply of personnel, the major bottleneck on Soviet mobilisation was the availability of equipment, and the ability to supply and support such a large force in the field. This is demonstrated by the fact that only about 2 000 000 (out of 4 000 000) people actually joined the fighting troops, (in operational fronts or armies), via the people's militia. [59] This possible over-mobilisation (i.e. excessive personnel and correspondingly insufficient weapons and transports) resulted in many new combat units of very dubious combat value whilst simultaneously having a detrimental effect on the Soviet's war economy. The combat units of questionable value included militia fighter battalions and most of the separate Red Army rifle brigades. These units had little heavy equipment,

almost no transport and support systems, and even less training. However the Soviet mobilisation process did result in a great many combat units of this type, so provided the human cost in casualties could be endured, it is debatable whether the term ‘over-mobilisation’ is appropriate.

In addition, the FILARM model serves to demonstrate why a massive army in the field, containing a huge number of combat units without adequate support infrastructures, can actually reduce the force’s overall Supply Distribution Efficiency (SDE). All combat units in the field still have to be fed, clothed, sheltered, equipped, maintained, refuelled and resupplied etc, regardless of size and combat value. The larger the army in the field at any point in time, the greater the demand on supply and support infrastructures. I t should be remembered that as soon as mobilised personnel don a uniform and enter training, they are no longer producing goods or remain self-supporting: they have to be supported by the resultant reduced war economy and whatever transport systems exist. The Red Army faced this problem for most of WWII and particularly in 1941, despite large numbers of transport vehicles being commandeered from civilian use. The main reason the Soviet Army’s SDE didn’t simply collapse in 1941, is that the actual army in the field (being continuously supplied) remained at around 4-5 000 000 and never grew to twice that size. This was because the mobilisation of new units and replacements barely kept up to the staggering losses through 1941. The Soviets admit to 4 473 820 casualties in 1941 from all causes, although this appears to be a low figure as discussed in Appendix B. [60]

The true extent of the personnel vs. equipment bottleneck in the USSR in 1941 only becomes apparent from the Soviet FILARM model. The model clearly demonstrates that the brake on the Soviet mobilisation rate in 1941, and its ability to support such a massive army in the field, was limited by available equipment (including transport). This was the case even though the Red Army and Red Air Force (VVS) enjoyed by far the largest stockpile of weapons in the world in June 1941. Even more importantly, <u>the FILARM model enables us to quantify this effect for analysis and for any military simulation.</u>

To a large extent the bottlenecks in the German mobilisation process were the opposite to that of the Soviets. Because the Germans under-mobilised immediately prior to Operation Barbarossa, their mobilisation rate in 1941 was limited more by the availability of trained personnel than by availability of equipment. The German figures show that in certain weapon areas they had more equipment available, either stockpiled or in production, than was used in either Operation Barbarossa or on other fronts at that time. Post-WWII accounts usually focus on the low German production figures for 1941 and 1942, to illustrate the lack of clear strategic thinking and planning in the German war economy. Germany (at war since 1939) was at war with the USSR, USA and the entire British Empire, and was suppressing most of Europe by the end of 1941. Yet, German production didn't get onto a war footing until 1943, just a little too late!

Nevertheless, German war production was significant and the German FILARM model shows that (for whatever reasons) they didn't release what they had to the Wehrmacht forces on the Eastern Front in 1941. These figures are especially glaring in relation to tanks and assault guns. Almost certainly the same apparent over confidence caused the German war planners to underestimate the personnel replacements which would be needed for Operation Barbarossa. The Germans planned 475 000 Army and Luftwaffe replacements for the first three months of Operation Barbarossa, by which time most senior German officers and leaders assumed the USSR would be on the verge of collapse or already conquered. [61] Unfortunately for the Axis powers, the casualty estimate was quite accurate but the Red Army was still far from collapse by October 1941. The Germans had suffered 559 994 casualties, from all causes, by the end of September 1941 and 839 855 by the end of 1941. [62]

During 1941 the Germans generally sent replacement to the front after they had been properly trained in army replacement battalions. This meant the German army replacements were trained to a much higher standard than their Soviets counterparts, but there were far fewer of them. The longer training period also meant that there was a considerable delay between the German command belatedly realising that more replacements were desperately needed, and their arrival at the front. The result was that most of the newly mobilised German replacements arrived after 1941, and the

German replacements in the German FILARM model are limited to the trained personnel that were historically available. In this case the German FILARM model serves to underscore the failure of contingency planning at the strategic level in the German High Command in 1941.

In conclusion, unless a Fully Integrated Resource Model (which includes all available personnel and equipment) is used as the foundation of any military simulation the size of Operation Barbarossa, it becomes almost impossible to quantify the various constraints and limitations on the combatant's mobilisation processes. It becomes very difficult and impractical to accurately quantify the total resources available to reinforcements, replacements and any supporting infrastructures. In simulations without a Fully Integrated Resource Model, the simulation designer or author is reduced to making an educated guess. This is the key difference between qualitative comments on military history and a quantitative analysis.

Finally it should be noted that the Fully Integrated Resource Model is especially powerful and successful when most of a country's war economy and resources are thrown into a particular campaign. In Operation Barbarossa this applied to the Soviet Union and Finland, and to a lesser extent to Germany. This will become readily apparent to the reader upon examining the respective FILARM model data in detail.

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b. The Actual Personnel and Equipment Present

An Integrated Land and Air Resource Model **ensures the actual personnel and equipment present in all combat units (from large divisions to small corps units) are accurately represented**, and these **combat units are not simply represented by the unit's official Table of Organisation and Equipment (TOE)**.

In any analysis or military simulation claiming to be realistic and historically accurate, the <u>actual</u> personnel and equipment present in any combat unit must be used to calculate the maximum combat power of that unit at that time. The actual personnel and equipment present is used in

conjunction with other factors such as Relative Overall Combat Proficiency (ROCP) and Supply Distribution Efficiency (SDE).

Historically, very few countries had sufficient trained personnel and equipment to meet all the demands placed on their armed services. The army would generally issue TOEs it believed were required to do the job, as well as having some chance of being fulfilled with the available resources. Even in peacetime, the actual personnel and equipment available was usually considerably lower than the TOE in most combat units, and after hostilities started this difference often became extreme. In actuality newly mobilised units were often thrown together with ad hoc equipment from various sources including obsolete weapons from old stock, equipment from disbanded units, and newly manufactured equipment.

Many military simulations base the calculated combat strength on TOE (as this is usually readily available through records) and it is obvious why this is a mistake if historical accuracy is the aim. For example, if Soviet divisions in an Operation Barbarossa simulation are simply given sufficient equipment to meet there TOE, then the Soviet FILARM model shows us that the simulated Red Army contains far more equipment than existed in the entire USSR from 22nd June to the end of December 1941. [63]

Combat units did occasionally reach or even exceed their TOE in WWII. However this was usually at the start of a major campaign, and was due to the stockpiling of weapons, transport and supplies before combat operations started. For example, many German units on the East Front on 22nd June 1941 were close to their TOEs, and several Western Allied units before D Day (6th June 1944) were actually well over their TOEs.

c. Combat Unit Mobility

An Integrated Land and Air Resource Model **enables an accurate calculation of the actual mobility of combat units on the battlefield**.

The mobility of combat units on the battlefield is directly related to the actual equipment present in any particular unit (see b. above).

It should be remembered that divisions were (and still are) usually the smallest self-contained combined arms units on the battlefield. They normally included infantry, artillery, combat engineers, signal units, and all the supply and support infrastructures required for the division to be self-supporting and to operate independently. The TOE of any division was generally calculated with sufficient transport (including horse drawn transport) to be able to 'lift' and move the entire division, including any support infrastructures. This was the case unless the division was specifically designed for a static defence role, such as a fortification unit or a coast defence static division. Some divisions were designated to receive additional transport when the unit was expected to move, but such units tended to be rare: usually, they were either special units (such as airborne units) or the higher headquarters was husbanding their transport resources. 64

If a division's actual transport strength was well below its TOE strength, then its mobility was much more restricted then if it was at its full transport TOE strength. Without adequate transport available, divisions were unable to fully utilise their disparate sub-units. A division was generally unable to move and fight as a complete unit and it struggled to act independently of other combat units. In other words it was much less able to function as a self-contained combined arms unit. The division's actual mobility was critical in battle, and in many cases the heavy equipment was left behind either permanently (if in retreat) or temporarily (if advancing rapidly).

Transport in Operation Barbarossa involved horses with wagons and carts (lots of them!) , trucks, light transport, motorcycles and prime movers (tractors and halftracks). Each of the major combatants involved in Operation Barbarossa had different transport TOEs, vastly different available transport and hence widely varying 'mobility factors'. Thus two horse-drawn infantry divisions from different countries may look similar organisationally, but that doesn't mean they had anything like the same actual battlefield mobility. Unless the actual transport available to the various combatants is carefully simulated (as is the case using the FILARM model), a military simulation has little hope of reproducing the actual combat unit mobility or the real circumstances of a battle or campaign.

d. Efficiency of Supporting Infrastructures

An Integrated Land and Air Resource Model **enables an accurate calculation of the maximum efficiency of any supporting infrastructures**.

This is the so called Supply Distribution Efficiency (SDE), discussed in detail later. [65]

A combatant's SDE was vital to sustaining prolonged combat operations, and was especially important in any mobile operations. The SDE calculation includes the combat unit's internal support infrastructures (e.g., the divisional support elements within all participating divisions) as well as any corps and army level support infrastructures. If the trucks, tractors and other support equipment were never manufactured and never received by an armed force, then the supply and support available to that force was dramatically reduced. This effect has to be quantified carefully for each army and air force because it can decide the outcome of any given battle or campaign before it even starts.

In the first months of Operation Barbarossa, both sides had massive supply and support problems. The Germans were continuously conducting mobile operations, which require more than a basic support infrastructure. They were doing this as their supply lines grew longer along bad roads, and (temporarily at least) further away from their supply railheads. Therefore the available motorised transport, and the railroad construction and operation units, were critical to their operations.

The Soviets suffered from a chronic shortage of almost all types of transport. They were closer to their supply sources and railheads and could stockpile more supplies in static defences. However their mobility was limited and they had a massive amount of heavy equipment (considerably more tanks and heavy guns than the Axis forces), which needed even more support than usual. Also, the Red Army had to scrape together sufficient transport to launch more than token counter-attacks (with their large mechanised corps) in order to avoid simply responding to the Axis offensive initiatives.

The FILARM structure enables the SDE of the Soviet and Axis forces to be accurately ascertained, without which any realistic military simulation is severely compromised.

e. Replacements

An Integrated Land and Air Resource Model **enables the number and type of replacements available during a campaign to be ascertained, as well as the replacement distribution**.

In many military campaigns (not least Operation Barbarossa) the outcome was largely affected by the replacements received by combat and support units during the campaign. Replacements represent the movement of trained personnel and equipment into combat units in an effort to replace those lost, primarily due to combat. Personnel replacements can take the form of infantry squads, personnel crewing heavy weapons, and personnel going into support infrastructure. Equipment replacements take the form of weapons, transport and any other equipment listed in a unit's TOE.

The Integrated Land and Air Resource Model enables the total number of available personnel and equipment replacements to be ascertained, and it enables the distribution of replacements to be determined based on the usage of personnel in the overall war effort. For example, if 70 000 trained infantry replacements and 30 000 trained artillery replacements were available over a given time period, but only 10 000 artillery replacements were required because insufficient artillery pieces were available, then a maximum of 90 000 infantry type replacements (including 20 000 less well trained) were actually available provided there was adequate numbers of small arms available to equip them all. Generally, the combat units in question attempted to rebuild their organisations according to the current authorised TOE. Overall replacement strategy was determined by the resources available, the political culture, and the relevant high command's doctrine and strategic plans.

In 1941 the Soviet strategic planners rapidly realised they were in a fight for their lives and the Soviet Union mobilised for total war very early in the campaign. During Operation Barbarossa the Soviets directed the majority of their resources into creating new combat units, but they also

mobilised massive numbers of troops as replacements, mainly in the form of rifle troops with little or even no training. As such, the Soviet Fully Integrated Land and Air Resource Model is critical in determining the maximum personnel and equipment used by newly mobilised combat units, while simultaneously determining the actual resources that were available for use as replacements in existing units. The model tends to highlight the true extent of the Soviet war mobilisation, but it also underscores weaknesses in the newly mobilised Red Army which could potentially have proved fatal to the USSR in 1941.

The Wehrmacht had calculated (many would say gambled) that the campaign in the East would be of a short duration. Examination of monthly listed force strengths (personnel) reveals that their replacements and reinforcements kept pace with losses for most of 1941. However the Germans only had sufficient replacements in the form of trained personnel to maintain their critical attack units, particularly panzer and motorised divisions, near their TOEs until September-October 1941. By October the Germans had used most of the ready and relatively well trained replacements which were available in June 1941. It was mainly poor strategic contingency planning, as well as Wehrmacht doctrine, that prevented personnel recruited in the second half of 1941 from being sent to the East Front until 1942. The German equipment replacements (particularly tanks) were even more mismanaged at the strategic level. Incredibly, the Germans downgraded their replacement army and war economy immediately prior to and in the early stages of Operation Barbarossa. In addition the Germans appear to have held back certain critical replacements such as tanks, apparently to build up new units in the west.

All these factors are modelled in the German Fully Integrated Land and Air Resource Model. In this case the actual replacements sent to the East Front are used, and the model serves to highlight the strategic blunder of invading the USSR whilst simultaneously downgrading your war economy!

f. New Equipment

An Integrated Land and Air Resource Model **ensures combat units do not receive new equipment historically too early or too late in the**

campaign.

This result is automatic in a good Fully Integrated Land and Air Resource Model.

If the TOE of combat units is used as the primary indicator of strength in any military simulation (as opposed to each unit's actual strengths) then specific weapons and other equipment are often assumed to have been available when historically this was not the case. This is because TOEs often called for new equipment that was still in the later stages of testing, was not yet in series production, was still in very limited production, or was not yet released to combat units for technical reasons.

A good example of this in 1941 is the availability of Soviet anti-tank rifles. According to the 29th July 1941 rifle division TOE (or Soviet *Shtat*), a rifle division was authorised 18 14.5mm PTRD 1941 or 14.5mm PTRS 1941 anti-tank rifles. However AT rifles were only generally issued in November 1941 because ammunition for them was not in production until late in 1941. This was the case even though AT rifle production started well before June 1941. [66] Red Army units fully equipped with AT rifles often appear far too early in many Barbarossa simulations, particularly in tactical-operational level simulations.

In other cases a weapon system may have been available in significant numbers, even though common perception is that only a few were available. Because the FILARM model is tracking all significant resources (including production and numbers in service) it ensures that newly available weapon systems are included in the actual strength of units, and at the historically correct time.

An example of receiving equipment too late in some Barbarossa simulations is the T-34 tank (a very famous example in fact). Many accounts of Operation Barbarossa claim, or at least imply, that the T-34 surprised the German Army in the winter counter-offensive of 1941. Some military simulations follow this line. In fact, on 22nd June 1941 the Soviets had already manufactured 1 225 T-34s, of which 957 had already been allocated to combat units or were in training units or depots. [67] Of these,

918 T-34s were available for combat in the Western Military Districts in June-July 1941. [68] Almost all these tanks were irrecoverably lost from June to August 1941. By the end of 1941 the Red Army had lost 2 300 T-34s, most of them well before the winter counter-offensive. [69]

g. Operational Freedom of Action

An Integrated Land and Air Resource Model **allows the military simulation 'commander' to have the same level of operational freedom as the historical protagonists**.

The Soviet FILARM model highlights the fact that a substantial number of new divisions, which the Soviets are credited with mobilising in 1941, were in fact existing divisions that were simply renamed (and occasionally revamped). Essentially, the Soviets officially disbanded many of these units by simply renaming them as a 'new' units, and usually (but not always) adding some additional resources from reserves. [70] As the underlying principle of the integrated resource model is 'the conservation of resources' within the armed forces of a country, then in order for these 'new' divisions to come into existence, the existing 'old' divisions (providing the resources) have to be removed from the Order of Battle (OOB).

However if all unit 'disbandments' are pre-ordained and hence pre-programmed into a military simulation according to historical timelines, it would have a severe and unrealistic impact on the operational options available to the Soviet simulation 'commander'. Historically the Soviets would not have disbanded or reorganised a division in the middle of a battle, where it would most likely be holding a critical position. Correspondingly in the simulation, an artificial situation would occur where the Soviet simulation commander would always be in danger of losing a division in the line at a critical moment. In fact, his or her entire strategy in the simulation would be dictated by the historical disband decisions made in a potentially different situation and a different historical context. The simulation commander would have much less freedom of action in planning their campaign than the historical commanders did.

For example, the 131st Mechanised Division (9th Mechanised Corps-Southwestern Front) was renamed the 131st Rifle Division on 3rd July 1941, after being committed to heavy combat in June 1941. Most of its tanks in its tank regiment were gone by early July 1941 and a new rifle regiment was added from reserves to replace its expended tank regiment. This is the historical context.

Now consider what might happen if the Southwestern Front's simulation commander has managed to keep his 9th Mechanised Corps intact through June 1941 by not committing it to combat, and building it up with replacements in a rear area. This was historically not the decision made. In the simulation, the Soviets are therefore ready for a major counter-attack against Army Group South in early July 1941. The counter-attack's success depends on the tanks and mobility of the corps' 131st Mechanised Division. Suddenly (on 3rd July), without ever going into combat, the 131st Mechanised Division becomes a relatively immobile rifle division with no tanks and few trucks: these have all gone into reserve. Subsequently the counter-attack cannot happen, even though the units involved had never seen combat! The simulation is implementing a command decision made in a completely different historical situation. In other words simply implementing decisions made in a historically different context, can lead to unrealistic restrictions and ahistorical situations. Unfortunately in many existing simulations of Operation Barbarossa (and other military campaigns) this is exactly what happens.

The reader should bear in mind here that as the simulation commander, higher command decisions (including disbandment of combat units) should become yours. The decision to either, immediately commit the 131st Mechanised Division into combat (as was done historically), hold it in reserve for a counterattack, or simply disband it for its resources, should be the simulation commander's. The actual historical decision was made by the Soviet high command based on the specific historical situation at that time: the simulation commander should be allowed at least the same freedom of action as the historical protagonists. The disbandment of the 131st Mechanised Division should therefore not be pre-ordained, and hence pre-programmed, in any military simulation striving to achieve historical accuracy and avoid unrealistic situations.

The FILARM model realistically simulates the effect of different command decisions, whilst still keeping the military simulation in historical context. For example, if the 131st Mechanised Division was immediately disbanded in the simulation, then the 131st Rifle Division would arrive on the battlefield at approximately one third strength (representing the genuinely new rifle regiment from reserves), and other Red Army combat units would benefit from additional replacements. Alternatively if the 131st Mechanised Division was held in reserve for a counter-attack, then the counter-attack combat would be resolved, the 131st Rifle Division would arrive on the battlefield at approximately one third strength, and other Red Army combat units would not receive the additional replacements. In short, the power of the FILARM model allows realistic operational freedom of action because it works as a complete system.

A way of preserving the integrated model, not limiting the operational options open to any simulation commander, and not reducing the historical mobilisation schedule, are examined in detail in Volume III of this work: 'The Soviet Armed Forces, Mobilisation and War Economy from June to December 1941'. [71]

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[52] This occurred in 2 great convoys around the 26th of August 1941. The two convoys had 84 and 78 ships (including the cruiser Kirov and 18 destroyers of all types). They evacuated approximately 30 000 men, but left around 11 500 to their fate. The operation was very expensive in terms of ships and loss of life at sea. Losses amounted to 5 destroyers and 41 other ships, with the Kirov and many others damaged.

[53] For this operation the Germans assembled around 100 ships and 180 'assault boats'. The entire Soviet Garrison was lost, approximately 15 300 captured and 4 700 killed, with all heavy guns. German killed, wounded and missing were reported at 2 850. V.B. Borries, T. Curtis, Barbarossa: Army Group North 1941, GMT, Hanford CA, 2000, Scenario outcomes, p. 19.

[54] On the night of 25-26th December 1941, the Soviets attempted 25 separate landings in 10 different areas of the Kerch peninsula (only 4 landings were successful). From the 28th to 31st December 1941, 40 000 Red Army troops stormed and occupied the port of Feodosiya on the Crimea's southern coast. The Oxford Companion to WWII, Dear, I.C.B. (ed.) , Oxford University Press, New York, 2001, p. 107.

[55] C. C. Sharp, 'Red Death': Soviet Mountain, Naval, NKVD, and Allied Divisions and Brigades, 1941 to 1945, Soviet Order of Battle WWII: Volume VII, George F. Nafziger, West Chester, OH, 1995, p. 28.

[56] For example, only 5 U Boats were initially made available, while the Admiral Scheer and Tirpitz were the only capital ships made available to the Baltic Fleet (*Baltenflotte)* for a very short time in September 1941. H. Boog, et al. (German Research Institute for Military History at Potsdam), Germany and the Second World War, Volume IV: The Attack on the Soviet Union, Oxford University Press, New York, 1996, pp. 376-384.

[57] C.C. Sharp, 'Red Tide': Soviet Rifle Divisions Formed From June to December 1941, Soviet Order of Battle World War II: Volume IX, George F. Nafziger, West Chester, OH, 1996, pp. 2 and 3. This figure may have been as high as 10 000 000. D.M. Glantz, Stumbling Colossus, University Press of Kansas, Lawrence, Kansas, 1998, p. 298, note 11. Also C. C. Sharp, 'Red Volunteers': Soviet Militia Units, Rifle and Ski Brigades 1941-1945, Soviet Order of Battle WWII: Volume XI, George F. Nafziger, West Chester, OH, 1996, p. 1.

[58] G. F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, Colonel General G.F. Krivosheev (ed.) , Greenhill Books, London, 1997, p. 9, table A.

[59] Ibid, p. 229.

[60] Ibid, p. 97, table 69.

[61] H. Boog, et al, (German Research Institute for Military history at Potsdam), Germany and the Second World War, Volume IV: The Attack on the Soviet Union. Oxford University Press, New York, 1996, p.317. Also, R.H.S. Stolfi, Hitler's Panzers East, University of Oklahoma Press, Norman and London, 1991, p. 155.

[62] R. Kershaw, War Without Garlands: Operation Barbarossa 1941/42, Ian Allan Publishing, Shepperton, UK, 2000, appendices 1, p. 251.

[63] Refer to Part I 8. - 'Military Simulations, and The General Structure of the Integrated Land and Air Resource Model - The Heterogeneous Model vs. the Homogeneous Model', for details on the methods used to establish the actual personnel and equipment in combat units, within the FILARM model.

[64] An example of 'husbanding transport resources', was the Italian 9th 'Pasubio' and 52nd 'Torino' (Semi-Motorised) Infantry Divisions, committed to support Operation Barbarossa from July 1941.

[65] Refer Volume I, Part I 9. – 'Supply Distribution Efficiency (SDE)'. Also refer to the relevant chapters of Volume II, III and IV: the SDE chapters in the German, Soviet and German Allied ILARM models.

[66] G. F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 246, table 95. Also, C.C. Sharp, Red Tide: Soviet Rifle Divisions Formed From June to December 1941, Soviet Order of Battle World War II: Volume IX, George F. Nafziger, West Chester, OH, 1996, p. 119.

[67] S. Zaloga, P. Sarson, T36/76 Medium Tank 1941-1945, Osprey Military (Reed International Books), London, 1994, p. 9. Also refer Volume III 6. 18) a. - 'The Actual Strength of all Soviet Land Combat Units in a Deployed (D) State on 22nd June 1941 - The Soviet Tank Deployment Matrix - The Deployment and Composition of Red Army and NKVD Armoured Forces on 22nd June 1941'.

[68] Ibid. Includes: 863 T-34s in Deployed (D) units in the Western Military Districts, 9 T34s in the South Western Front training and repair, 30 T-34s picked up by the 1st Mechanised Division from

training units in Moscow while on its way to the front as part of Stavka Reserves, and 16 in 50th Tank Division in Stavka Reserves.

[69] G. F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 252, table 95.

[70] Refer to Volume I, Part I 3. 4) e. – 'The Structure of the Fully Integrated Land and Air Resource Model (FILARM) - Combat Unit Processes Inside the FILARM Model - Disband and Shatter process' for an explanation on the use of the 'disbandment processes' in the FILARM model. This process enables existing resources in existing combat units to be used in forming so called 'new' combat units.

[71] Refer to Volume III - 'The Soviet Armed Forces, Mobilisation and War Economy from June to December 1941', chapter title 'Soviet Mobilisation After 22nd June 1941: The Actual Strength of all Soviet Land Combat Units Mobilised from 22nd June to 31st December 1941'.

3. The Structure of the Fully Integrated Land and Air Resource Model (FILARM)

As stated previously, the two key underlying principles involved in the Integrated Land and Air Resource Model are ‘ **the conservation of resources**’ and ‘ **the model is an interactive system**’. The ‘conservation of resources’ principle dictates that resources cannot be created from nothing and they cannot disappear, unless destroyed or scrapped. The resources are defined as the personnel and equipment involved. The ‘model is an interactive system’ principle determines that any change in any part of the model has a direct cascade effect on many other model components.

With this in mind, the structure of the Fully Integrated Land and Air Resource Model (FILARM) is shown in the resource allocation flow-diagram shown in diagram FILARM. The Fully Integrated Land and Air Resource Model consists of the following components:

i. A model representing all resources present in all armed forces at the start of the campaign, and all resources received from all sources during the campaign (symbolised by the enclosed thick-line boundary)

ii. 3 resource sources and 1 resource destination, outside the model (dashed-line bordered boxes).

iii. 3 paths by which resources can physically enter the model (dotted lines).

iv. 2 paths by which resources can physically exit the model (dotted lines).

v. 21 lines and directions by which resource reallocation can occur within the model (solid lines).

vi. 7 ‘ **resource allocation states**’ inside the model, made up of:

- Deployed (D) Combat Units, Mobilised and Deployed (MD) Combat Units, Mobilised and Not Deployed (MND) Combat Units (grey filled boxes).
- Supply and Support Infrastructure (a dot filled box).
- Replacements (R), Campaign Start Reserves, and Campaign Reserves (dashed-line filled boxes).

vii. 5 ‘ **combat unit processes**’ (blank boxes). Combat units must undergo one or more of these processes in order for any resources to be reallocated to combat units within the model, or for any resources to leave the model as irrecoverable losses.

The following is a detail definition of each of the concepts, components, terms and processes used in the FILARM model. Figure FILARM 1 shows the components of the model, the flow of resources into and out of the model, the allocation flow of resources when they are in the model, and the processes that ‘allocated resources’ must undergo to be reallocated.

In some cases, real life examples are given to illustrate the definition or concept used, but complete details are shown in the individual country’s FILARM or PILARM model data (i.e. Volumes II, III and IV).

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General Structure of the Fully Integrated Land and Air Resource Model: (FILARM)

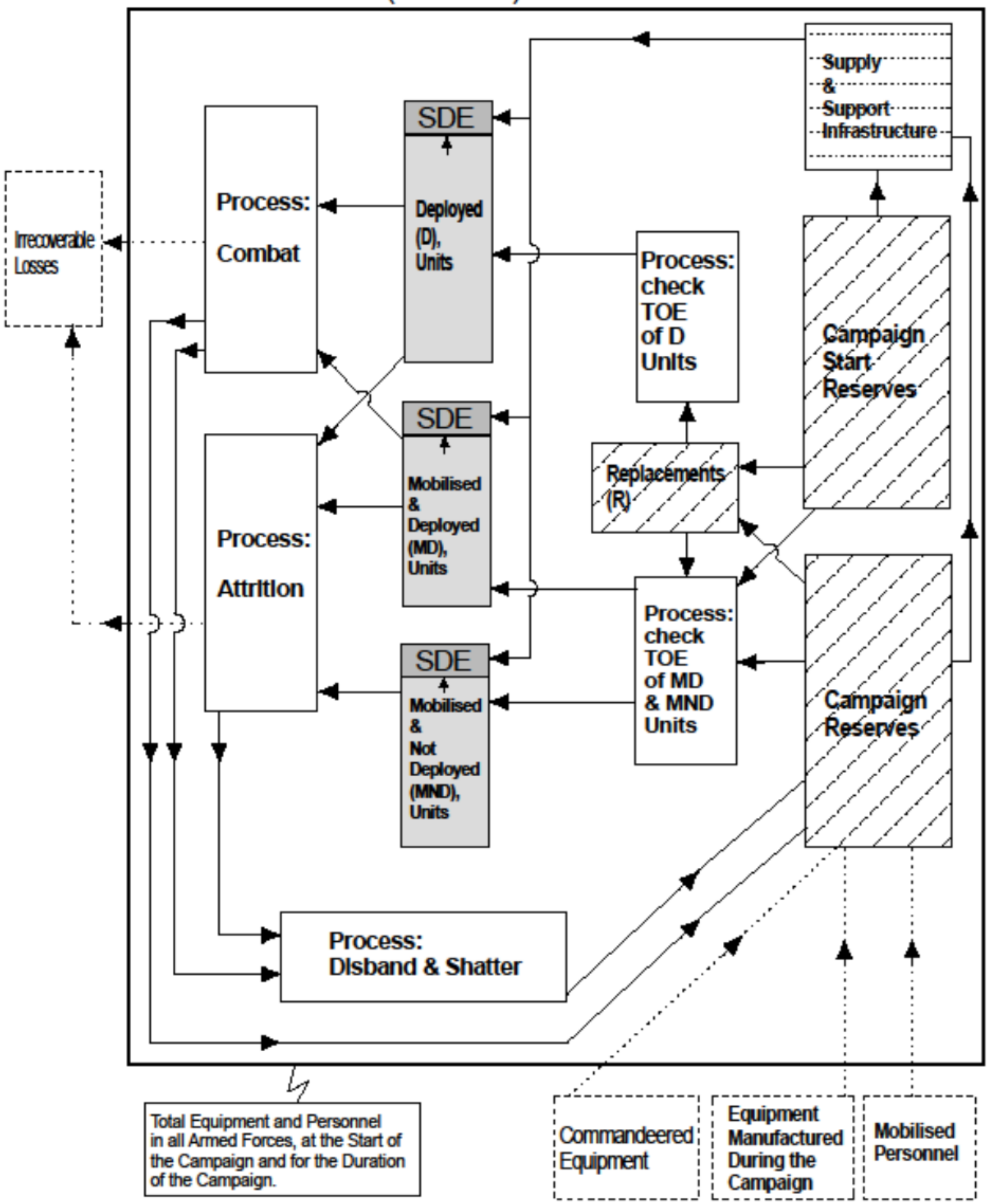

Fig FILARM

1) Resource Sources, Destinations and Paths outside the FILARM Model

The thick-line boundary

The enclosed thick-line boundary in diagram FILARM represents the fully integrated resource model's limits. All resources present at the start of the campaign, and all resources received from all sources during the campaign period, are within the model. The term 'fully' means that all resources, in all physical locations (i.e. all fronts and rear areas) are included.

The thick-line boundary conceptually represents the conservation of physical mass, with the 'mass' being the total resources in that county's armed forces. The only way this can increase or decrease is by resources entering (i.e. new resources) or exiting the model (i.e. irrecoverable losses) along one of the dotted lines (refer below).

The dashed-line bordered boxes

The dashed-line bordered boxes in diagram FILARM represent resource sources and losses. All new resources must come from 'Manufacturing', 'Commandeered Equipment' or 'Mobilised Personnel'. For this purpose equipment received from the Western Allies via Lend Lease is considered to be the same as manufactured equipment.

For the Soviet Union, Germany and Finland all relevant equipment manufactured during the campaign is put into the model. 'Commandeered Equipment' is more difficult and relates primarily to transport. This is very important for the Soviets as they commandeered most of their new transport from the civilian economy during Operation Barbarossa. Although Germany was equally dependent on commandeered vehicles, the large majority were already deployed at the campaign start with limited replacements after that.

For the Soviet Union, 'Mobilised Personnel' of around 9 500 000 is used as the base for the Soviet FILARM model. This is the number of additional personnel that will enter the model (i.e. be available to the Soviet

armed forces) from 22nd June to 31st December 1941. This is around 20 times greater than the newly mobilised personnel available to the Wehrmacht during this period. Detail analyses are used to examine these numbers, and the resultant forces, in the respective country's models. It should be pointed out, however, that the 'Mobilised Personnel' represents all trained and untrained personnel. About half of the Soviet manpower mobilised had little or no training, whilst the first 400 000 German replacements were of reasonably high quality. The effect of poorly trained replacements on a force's Relative Overall Combat Proficiency (ROCP) has to be built into the model.

The losses box represents 'Irrecoverable Losses' only. Recoverable losses remain within the integrated land and air resource model (refer to combat and attrition processes below, for definitions of irrecoverable and recoverable losses).

The dotted lines

The dotted lines in diagram FILARM represent resources entering and exiting the model.

Resources cannot be created, unless they enter the model from 'Manufacturing', 'Commandeered Equipment' or 'Mobilised Personnel'.

Resources cannot disappear (cease to exist), unless they exit the model via the 'Combat Process' or 'Attrition Process', as 'Irrecoverable Losses'.

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2) Resource Reallocation Paths within the FILARM Model

In diagram FILARM, the solid lines represent the resource reallocation paths (or resource allocation flow) within the FILARM model. The properties of the resource reallocation paths in the FILARM model are as follows:

i. In order for any resources to be reallocated from one 'Resource Allocation State' to another, they have to proceed along one or more of

these reallocation paths. **This is termed a ‘reallocation event’.**

ii. All resource reallocation paths are mono-directional.

iii. There are only 21 possible paths and directions along which resources reallocation can occur within the model.

iv. Resource reallocation can occur along alternative paths within the model, and the number of paths (lines) used during a particular reallocation event is unlimited.

v. A resource may have to go through several ‘Resource Allocation States’ and ‘Combat Unit Processes’ (described in succeeding sections) during a single reallocation event. Resource reallocation is not limited by the number of ‘Resource Allocation States’ and ‘Combat Unit Processes’ it may go through during a single reallocation event.

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Immediately prior to the campaign start, all resources are allocated to one of the following ‘Resource Allocation States’: ‘Deployed (D) units’, ‘Supply and Support Infrastructure’, ‘Replacements (R)’ or ‘Campaign Start Reserves’. After the campaign start, and once a resource has entered the FILARM model, it may be reallocated to any ‘Resource Allocation State’ except ‘Campaign Start Reserves’. Note there is no resource allocation path entering ‘Campaign Start Reserves’. Thus the resources in ‘Campaign Start Reserves’ only reduce during the period of the campaign, although many of these resources will be recycled via the ‘Campaign Reserves State’.

It is important to understand that **resource reallocation does not necessarily mean any physical movement of the personnel or equipment concerned**, although in reality it would probably involve some physical relocation. A particular resource may, and usually does, undergo both reallocation and physical relocation simultaneously.

For example, 30 new T-34 tanks left training units in Moscow in June 1941 and were reallocated to the 1st Mechanised Division, moving at that

time from Moscow to the Western Front. In the FILARM model, the reallocation event involved tanks being reallocated from Stavka reserves (part of the 'Campaign Start Reserves') to the 1st Mechanised Division (a Deployed (D) combat unit). The reallocation paths used were: from 'Campaign Start Reserves' to 'Replacements (R)', and then onto a 'Deployed (D)' unit via the relevant 'Check TOE Process'. Simultaneously the tanks physically moved from Moscow to the Smolensk area.

Resources are often reallocated without significant physical relocation.

For example, on 21st September 1941 the 1st Mechanised Division was formed into the 1st Guards Motorised Division. The unallocated resources resulting from 'Disbanding' of the 1st Mechanised Division (a Deployed (D) combat unit) were reallocated to the 'new' 1st Guards Motorised Division (a Mobilised and Deployed (MD) combat unit), without physically moving any significant distance. In this case the complete sequence of processes and resource reallocation is represented in diagram FILARM as follows: Resources were reallocated from units in a D state, via the 'Attrition Process' and the 'Disband and Shatter Process', to the 'Campaign Reserves State'. Then the resources were reallocated, via the 'Check the TOE Authorisation of a MD or MND Unit Process', to a MD combat unit. This is one of many examples in the Red Army during Operation Barbarossa, where a combat unit was disbanded with the specific plan of reallocating all its resources, and part of its initial TOE structure, to form a 'new' unit. The properties of the resource reallocation paths in the FILARM model (detailed above), is a very important part of the Soviet FILARM model's 'Disband and Shatter Process'. [72]

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The reader should note that, **the direction of the arrows on the reallocation paths (lines in diagram FILARM) strictly represents resource allocation flow direction**.

For example, resources in all combat units can only return to the 'campaign reserves' as recoverable losses due to combat or attrition, or if the combat unit to which it is allocated is disbanded or shattered. To enable

the reader to further grasp how resource reallocation works in the FILARM model, consider the following historical example.

A new T-34 tank was manufactured in Stalingrad in June 1941. The 8th Tank Division (Deployed (D) on 22nd June 1941 in the Kiev Special Military District) was fighting against Army Group South, and had fewer than half its initial complement of 140 T-34s left by July 1941. The new T-34 was reallocated to the 8th Tank Division as a replacement in August 1941 (at Dnepropetrovsk, where the division was stationed in reserve). In mid-September 1941 the 8th Tank Division was disbanded, and its two tank regiments were used to form the 130th and 131st Tank Brigades, both with TOEs authorising T-34s. The original (new) T-34 survived long enough to be transferred to the 130th Tank Brigade in September, but was lost in combat near Rostov in late 1941.

In the FILARM model, the above example involves two distinct reallocation events. In the first event, the T-34 resource enters the model from ‘Equipment Manufactured During the Campaign’, and goes into ‘Campaign Reserves’. Stavka reallocates the tank as a Replacement (R). After checking that 8th Tank Division’s TOE authorises T-34 tanks (the ‘Check the TOE Authorisation of a Deployed (D) Unit Process’), the T-34 is reallocated to the 8th Tank Division from Replacements (R). Therefore the resource was reallocated from ‘Campaign Reserves’ to a ‘Deployed (D) combat unit’, and will physically move from Stalingrad to South West Front.

The second reallocation event occurs when (or if in the simulation) the 8th Tank Division is disbanded. In this case the T-34 is reallocated via the ‘Attrition Process’, the ‘Disband and Shatter Process’, the ‘Campaign Reserves’, the ‘Check the TOE Authorisation of a MD Unit Process’ (to check September 1941 tank brigades are authorised T-34s), and to the new 130th Tank Brigade. Therefore the resource was reallocated from a ‘D combat unit’ to a ‘MD combat unit’, without any significant physical relocation.

Lastly, in late 1941, the T-34 goes through the ‘Combat Process’ and exits the integrated land-air model as an ‘Irrecoverable Loss’.

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3) Resource Allocation States inside the FILARM Model

As stated previously, there are seven possible ‘Resource Allocation States’ inside the FILARM model, made up of: ‘Deployed (D) units’, ‘Mobilised and Deployed (MD) units’, ‘Mobilised and Not Deployed (MND) units’, ‘Supply and Support Infrastructure’, ‘Replacements (R)’, ‘Campaign Start Reserves’ and ‘Campaign Reserves’. The D, MD and MND states are ‘combat capable’ states and units in these states are therefore referred to as ‘combat units’.

a. Combat Units: D, MD and MND

The three grey filled boxes in diagram FILARM represent combat units in the armed forces to which resources are allocated. In the FILARM models simulating Operation Barbarossa, the armed forces include army, air force (including naval air), militia, rear area support, and naval personnel seconded to the army. All combat capable organisations (or combat units) in the armed forces have a TOE regardless of size. They are specifically categorised into one of the following:

i. Deployed (D)

The combat unit is deployed with a TOE anywhere in the armed forces on the first day of the campaign, in this case 22nd June 1941. The unit may be deployed at a fraction of its full TOE strength and it may be allocated to any military district or army.

The details and assignments of all units in a Deployed (D) status are detailed in the **Deployment Matrices** for each country. There is a separate Deployment Matrix for each of the land, air and naval forces deployed in Operation Barbarossa. [73]

ii. Mobilised and Deployed (MD)

The combat unit is mobilised with a TOE after the first day of the campaign, in this case 22nd June 1941, and allocated (or assigned) to an

‘Active Front or Army HQ’.

For the Soviets an ‘Active Front or Army HQ’ is any front or army HQ in the west USSR. In this case ‘west’ is defined as west of a line running north-south 100km west of the Urals. This therefore includes all front or army HQs in the USSR except those in the Urals, Siberia, Central Asia and Transbaikal Military Districts, and the Far Eastern Front. [74]

For Germany and Finland, an ‘Active Army HQ’ is any operational army HQ in the armed forces. Note, Germany had multiple theatres of war (or active fronts) in 1941, all with active army HQs. Even occupying forces (such as those in France, Norway and the Balkans) were still in active war fronts. These units were organised and operated on a war footing, and in most cases were carrying out military and security operations. Hence newly mobilised Wehrmacht units which were allocated to HQs in these theatres are considered to have been Mobilised and Deployed (MD). [75]

iii. Mobilised and Not Deployed (MND)

The combat unit is mobilised with a TOE after the 1st day of the campaign, in this case 22nd June 1941, and **NOT allocated (or assigned) to any ‘Active Front or Army HQ’.** An ‘Active Front or Army HQ’ is as defined as for the MD state above.

In addition, a unit which is created by a simple name change from an old unit without the addition of any new subunits from reserves is considered a Mobilised and Not Deployed (MND) unit. This is because the unit in question is already deployed on the battlefield and simply changes its name. In so doing the old unit ceases to exist. In effect the new unit becomes deployed, but the old unit it is replacing simultaneously becomes ‘un-deployed’. If no personnel or equipment are added from reserves, **then the net effect is that the deployment of new reserves is zero**. [76]

The MND state is of particular importance in the Soviet FILARM model because of their massive mobilisation program. Detail examination of each Soviet combat unit mobilised in 1941 shows that many were:

- Old units (usually divisions) with simple name changes, and were not 'new combat units' at all. Many of these divisions received no additional personnel and equipment from reserves (apart from Replacements (R) which is dealt with in a separate process). In this case the unit is classified as a MND unit.
- Old units (usually divisions) with simple name changes, and which were only partially new units. In these cases some personnel and equipment was added from reserves, usually in the form of a newly mobilised battalion or regiment. This was most common if the division type was also changed, which was common in the Red Army in 1941 (e.g., many existing mechanised divisions were changed into 'new' rifle divisions by simply changing their name and adding an additional new rifle regiment). In this case, only the newly mobilised portion of the so called 'new' combat unit is classified as MD, while the portion of the unit that 'came into existence' purely due to a name change is classified as MND. [77]
- Effectively paper organisations with only a commander and a few men (a cadre), and which were never assigned to an 'Active Front or Army' in 1941. In this case the unit is classified as a MND unit.
- Brand new units which had only started mobilising very late in 1941 and which were still barely formed before the end of the year. These units were not combat ready in any sense and not assigned to any 'Active Front or Army' in 1941. In this case the unit is classified as a MND unit. [78]

Discussion and detail of all MND units is carried out in each county's relevant FILARM and PILARM models.

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b. Supply and Support Infrastructure

The a dot filled box represents supply and support infrastructure outside the TOE of individual combat units, but within the structure of the armed forces, to which resources may be allocated. 'Supply and Support

Infrastructure' includes only non-combat capable units which may or may not have had a TOE. They include the following:

- All rear area corps, army, front and army group, supply and support organisations.
- Supply organisations working between railheads or ports, and corps or army supply depots. The latter is normally where combat unit (usually divisional) supply services pick up supplies.
- Rear area maintenance, repair, signal, intelligence and security organisations which are not normally capable of involvement in frontline combat (i.e. are non-combat units). Historically, some of these unit types were in actuality combat capable units. Examples were the German security divisions, NKVD rail security divisions, and some bridging engineer units. Note, all these unit types are already included as combat units with a TOE in a D, MD or MND state described above (even though many of these units were barely capable of direct combat and were really only designed for rear area support operations).
- Rear area air-force support, aircraft and airfield supply and maintenance, and air-force security and signal units, all of which are not normally capable of involvement in frontline combat.

The key parameters used to measure supply and support infrastructure in each FILARM model are the numbers of dedicated rear area personnel, as well as the overall lift capacity available in rear-area trucks, light transports, prime movers and horse drawn transport. From diagram FILARM we can see that 'Supply and Support Infrastructure' is critical in increasing a combatant's overall Supply Distribution Efficiency (SDE).

The other critical source of 'Supply and Support Infrastructure' is the support infrastructure within the combat units themselves (which are included in the TOEs of those combat units). This is indicated graphically in diagram FILARM by the dark-grey SDE box above each of the D, MD and MND 'Resource Allocation States'.

Therefore, the overall Supply Distribution Efficiency (SDE) of D, MD and MND combat units is a function of the rear area 'Supply and Support

Infrastructure' and the TOE infrastructure within the combat units themselves. [79]

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c. Reserves and Replacements (R)

The three dashed-line filled boxes in diagram FILARM represent reserves in the armed forces to which resources are allocated. Reserves in the armed forces may or may not have a TOE, and are not directly combat capable. They are categorised into one of the following:

i. Replacements (R)

'Replacements (R)' are personnel and equipment allocated to rebuild combat units which are in a D, MD or MND state, to the level of their currently authorised TOE. A unit may be below TOE strength due to loss of resources from combat, training and rear area attrition, or scrapping. Alternatively, it may be below TOE strength in its initial peacetime deployment and require newly mobilised resources to bring it up to full strength in time of war.

The latter condition is particularly important in the Soviet FILARM model because none of the rifle divisions in the Western Military Districts (or anywhere else in the Red Army), were at their authorised TOE strengths on 22nd June 1941. The divisions in the Far East came closest. Most rifle divisions were at the '6' or '12' level, indicating either 6 000 or 12 000 men on strength. [80] Despite having mobilised 500 000 men in the spring of 1941, to bring the rifle divisions in the Western Military Districts up to the '12' strength, most of these divisions contained considerably fewer than 12 000 men in June 1941. [81] Even a '12' strength division was well below the TOE, which authorised 14 483 men in a rifle division at this time. [82] In addition, most rifle divisions in the Western Military Districts were missing 33% to 66% of their horses and, much worse, 25% to 80% of their motor vehicles. They did however have most of their heavy weapons. The result was personnel weak, transport weak, and equipment strong divisions, which needed infantry and transport replacements as soon as possible.

The Soviet mobilisation plan called for these divisions to receive sufficient men and equipment to bring them up to full strength within 7-14 days of hostilities commencing. With regards to transport, this simply never happened: transport which was supposed to arrive from the civilian economy mostly never appeared, was diverted to newly mobilising units, or was overrun by the enemy before it could be commandeered and issued. However, in the case of personnel the Soviets did manage to mobilise 3 000 000 reservists in June and July 1941. These were immediately dispatched to the front to bring the divisions in the Western Military Districts up to strength. [83]

The Soviet FILARM model must therefore include this massive influx of manpower in June 1941, to bring any surviving Red Army divisions close to their authorised personnel at least. It is worth noting that the beauty of the integrated resource model is that if the Soviets (in a Barbarossa simulation) lose even more divisions in June and July 1941 than was historically the case, then this influx of replacements will be diverted into newly mobilising divisions, making them stronger more rapidly.

ii. Campaign Start Reserves

'Campaign Start Reserves', or existing reserves at the campaign's start, are resources not allocated to any combat unit in a Deployed (D) state at the start of the campaign. 'Campaign Start Reserves' include equipment and personnel in training and rear areas which may be in an active Military District, but which are not allocated to any combat unit. 'Campaign Start Reserves' may subsequently be committed to: any MD or MND combat unit, Replacements (R), or area support units (to improve SDE) during the course of the campaign.

'Campaign Start Reserves' include old or obsolete equipment, which may have been stockpiled for many years. It should be noted from diagram <u>FILARM</u> that the 'Campaign Start Reserves' box has no resources allocation entering the box. This means that the 'Campaign Start Reserves' are fixed at the campaign start, are subsequently used up during the campaign (e.g. Soviet), or are largely left unused for the duration of the campaign (e.g. German). Any resource exiting the 'Campaign Start

Reserves' (being assigned to another 'Resource Allocation State') may still end up in 'Campaign Reserves' if it is not irrecoverably lost. In this way an unassigned and obsolete resource (e.g. an old tank that started the war in storage) may still find itself assigned to various combat units over the course of its life. The Finnish Army's artillery park is probably the best example of this: they went into WWII with a lot of artillery dating from the 19th century; before hydro-pneumatic recoil systems were even invented!

'Campaign Start Reserves' were particularly important to the Soviets in 1941. The Soviet FILARM model shows that the Soviet's huge initial 'Campaign Start Reserves' were almost entirely used up to supply its massive mobilisation effort. Almost regardless of how old or in need of repair equipment was, practically all Soviet equipment went directly into MD or MND combat units, was allocated as Replacements (R), or went into supply and support infrastructure. Most of the really old and least serviceable Soviet weapons, particularly tanks and aircraft, went into MND combat units. Many of these newly mobilised units remained in the Far Eastern Front, and the Transbaikal, Central Asia, Siberia and Urals Military Districts from June to December 1941.

Conversely, a substantial portion of the equipment in the German 'Campaign Start Reserves' remained in reserves in Germany during the 1941 campaign. This equipment was not allocated to units which went into a MD or MND state during the campaign, including those in the Wehrmacht's Replacement Army. In addition, this equipment was not allocated as direct Replacements (R) for combat unit on the East Front or in North Africa.

The respective county's land and air resource models show the historical use of their 'Campaign Start Reserves' in detail.

iii. Campaign Reserves

'Campaign Reserves' are resources received during the campaign. Resources are received from 'Manufacturing', 'Commandeered Civilian Equipment' or 'Newly Mobilised Personnel'. In addition resources are received as recoverable losses after the campaign start via the 'Combat Process' and the 'Disband and Shatter Process' (refer processes below).

‘Campaign Reserves’ may be committed to any newly mobilising unit which then goes into a MD or MND state during the campaign, and they may be committed as Replacements (R) during the campaign.

Like the Soviet ‘Campaign Start Reserves’, the Soviet ‘Campaign Reserves’ were almost entirely used up to supply its massive mobilisation effort. In June 1941 the Soviet war economy was not geared up to the production levels it would achieve later in the war, and it was handicapped in the second half of 1941 by having to move large numbers of critical factories eastwards to the Urals. This took many factories offline for part of 1941-42. However Soviet production was still very large and proved critical to forming and supplying new units. The Soviet FILARM model clearly demonstrates that virtually all the Soviet ‘Campaign Reserves’ went into new units MD or MND combat units, were allocated as ‘Replacements (R)’ for all combat units, or went into ‘Supply and Support Infrastructure’ from June to December 1941.

In many traditional accounts of WWII, Germany comes under criticism for its low war production output from 1939 to 1942. However Germany’s war production was significant even in 1941, and the German FILARM model shows that a substantial portion of the equipment in the German ‘Campaign Reserves’ remained in reserves in Germany during the Barbarossa campaign. This equipment was not allocated to combat units which went into a MD or MND state during the campaign, including those in the Replacement Army. In addition this equipment was not allocated as direct ‘Replacements (R)’ to combat units on the East Front or in North Africa.

A good example is the Sturmgeschutz (StuG) III Assault Gun (Sd Kfz 142). If there was a weapon which should have been rushed to the East Front in 1941, it was this one. Between 22nd June and 4th July 1941, 301 StuG III Assault Guns were sent to the East Front. From July 1941 to January 1942 (inclusive) an additional 132 StuG IIIs arrived on the East Front with six new StuG battalions and the 227th Infantry Division, and an additional 7 remained in the German Replacement Army (in the west) in another newly forming battalion. [84] There were 377 assault guns available to the Wehrmacht on 1st June 1941 and a further 348 were received by the

end of 1941, of which 40 were received from manufacturing in December 1941. Yet despite this, only 15 StuG III Replacements (R) were sent to combat units on the East Front in 1941. [85] This means that a paltry 5% of the available assault guns were sent as Replacements (R) to the East Front in the second half of 1941 (15 out of a possible 285 unallocated). Even if we exclude the 40 StuG IIIs manufactured in December 1941, and maintain around 30 in the Replacement Army for training purposes, then around 200 additional StuG IIIs were still available to the Wehrmacht for use as Replacements (R) on the East front From July to December 1941.

All this was despite all the StuG battalions in the East being almost continuously in action and crying out for replacements from October 1941 onwards. This is especially striking considering that the Soviets were "scrapping the bottom of the barrel" with old and obsolete tanks to produce large numbers of tank brigades. One can only assume the new assault guns were earmarked for new battalions which were planned to be mobilised in the west in 1942. I'm sure the highly trained German StuG crews, who had lost their vehicles and were being wasted by fighting as infantry in the winter of 1941-42, would have appreciated the assault gun replacements sitting in reserve in Germany! The German FILARM model serves to highlight similar examples of what can be described as incompetent strategic planning and strategic overconfidence by the German High Command.

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4) Combat Unit Processes inside the FILARM Model

In diagram FILARM, the five blank boxes (with no filling) represent 'Combat Unit Processes'. **Combat units must undergo one or more of these processes for any resources to be reallocated within the model, or for any resources to leave the model** (as irrecoverable losses).

The 'Combat Unit Processes' in this context can be viewed as the effect of ongoing tactical and operational decisions, made by the various military commands, on an armed force's structure and allocation of resources. There

are five processes involved and they are categorised under the following headings.

a. Checking the TOE Authorisation of a Deployed (D) Combat Unit

The subject of TOEs (Tables of Organisation and Equipment) is discussed at length later in this work, and examined in detail in each of the combatant's respective resource models. [86]

All combat units and most non-combat units had a TOE, which set the framework for the organisational structure and authorised equipment for that particular unit. Even though most combat units were actually below their TOE strength, the TOE was still very important because it was created by the general staff of the military high command in order to meet the perceived demands that they believed were likely to be placed on their forces. As such, the various TOEs reflected the state of the tactical, operational and even strategic thinking in the armed force at that time. In addition, it made sense for the military high command to select a TOE which had a reasonable chance of being fulfilled with that country's available resources. In the FILARM models, the TOE is the structure that combat units will attempt to emulate during formation or by using Replacements (R).

For any Operation Barbarossa simulation, the 'Checking the TOE Authorisation of a Deployed (D) Unit' process will therefore check whether a particular land or air unit is authorised to receive the resource based on currently active **TOEs issued before 22nd June 1941**. If the unit is authorised by its current TOE to receive the resource then, depending on priorities, it may be allocated the resource.

It should be noted that TOEs were general orders issued to all units of a certain type. However there were often variations (from the standard) within the TOE of a particular combat unit, either relating to equipment or organisational structure. These differences in TOE were usually due to equipment availability. Sometimes more 'elite' or 'one off' units might have additional equipment and small organisational differences. In these cases individual combat unit TOEs are used in the FILARM model, reflecting the actual equipment the unit was likely to receive.

For example, the German 7th Infantry Division followed the overall TOE structure of a standard German first wave infantry division, except that it had two bicycle squadrons and no armoured cars in its reconnaissance battalion, and a slightly different supply infrastructure. This variation is therefore included in the specific TOE for the 7th Infantry Division, in the German FILARM model. Another example is Soviet tank divisions. The Soviet July 1940 tank division *Shtat* (TOE) authorised T-34 tanks. However most Soviet tank divisions in 1941 never received any T-34s, and they were mostly equipped with older T-26s and BT tanks in June 1941. In all these cases the tank types that were historically present are 'authorised' in the particular division's TOE. This is because it would be very unrealistic for a tank division with 200 BT-7s to receive a single T-34 as a replacement.

Finally it should be mentioned that a large proportion of military simulations make the serious mistake of using a combat unit's TOE as indicative of its actual strength before it went into battle. This usually occurs due to the absence of any other recorded information, or because they don't have an integrated resource model! Probably the best example in Operation Barbarossa of the frequently large difference between TOEs and actual strength is the Soviet 1941 mechanised corps. The Soviets had decided to abandon the tank corps structure in November 1939, following experience in Spain. However the Soviets realised they were originally on the right track when they saw the German results in France in 1940, and so they belatedly started reforming the massive mechanised corps (each with two tank divisions and one mechanised division). The order to form the first batch of eight mechanised corps and their component tank divisions came in June 1940, and another mechanised corps was ordered formed in November 1940. This meant nine mechanised corps and 20 tank divisions (including two separate tank divisions) were formed in barely six months. On top of this the Soviets made the rather amazing decision to form no fewer than 20 additional mechanised corps in February 1941. Consequently, on 22nd June 1941 most of the 29 existing mechanised corps were nowhere near fully equipped or combat ready, even though they all had very impressive TOEs! [87]

b. Check the TOE Authorisation of a MD or MND Combat Unit

This process is identical to the previous one, except it relates to **TOEs issued after 22nd June 1941** for newly mobilised units.

This process applies almost entirely to the Red Army and Red Air Force (VVS) in the Operation Barbarossa simulation, and is used extensively in the Soviet FILARM model. After the disastrous border battles in June and early July 1941, the Soviet high command quickly realised that they did not have the resources to fill the TOEs of the large pre-war divisions, and that they did not have the command, control or support systems to handle such large and unwieldy formations as the pre-war mechanised corps. To address this situation the Soviet high command quickly issued new TOEs which dramatically reduced the size and complexity of many existing division types. In addition, TOEs were issued for a whole range of new and smaller combat unit types, of which the 1941 rifle and tank brigades are the most well-known. These TOE changes are all detailed in the Soviet FILARM model (Volumes IIIA and IIIB).

Good examples of the rapidly changing TOEs in the Red Army from July to December 1941, are those issued for the tank and mechanised formations. A new reduced tank division TOE was issued on 10th July 1941, only 19 days after Operation Barbarossa commenced. On 15th July 1941 the mechanised corps HQs were disbanded and many mechanised divisions became rifle divisions (in terms of actual equipment, many of the pre-war mechanised divisions were almost rifle divisions anyway). [88] On 23rd August 1941 the Red Army temporarily abandoned the entire tank division concept, and new TOEs were issued for much smaller and easier to control tank brigades. Progressively smaller tank brigade TOEs were authorised on 13th September 1941 and again on 9th December 1941. [89]

Red Army rifle units changed in a similar fashion: new rifle division TOEs were issued on 29th July 1941, reducing personnel from 14 483 to 10 790 and reducing the heavy weapons by almost 50%. Another new rifle division TOE was issued on 6th December 1941. [90] In addition new separate rifle brigades were formed according to a new TOE dated 15th October 1941. These units were authorised only 4 356 men with only 24 45mm-76mm guns, and had virtually no support infrastructure. [91]

The Soviet FILARM model includes all new TOEs for all newly mobilised combat units, and all new TOE revisions within a particular unit type. Any new units which have a 'formation start date' on or after the 'TOE issue date' will be created with the latest TOE structure in the Operation Barbarossa simulation. [92]

A similar situation to the one above befell the Soviet Air Force (VVS) in 1941. The Soviets issued new reduced strength TOEs for their aviation regiments in August 1941. The air-model component of the Soviet FILARM model includes all the new TOEs for new aviation regiments (and other air units types) created after 22nd June 1941.

c. The Combat Process

This is essentially the process of battle. The day to day tactical and operational decisions made by the military command are represented by the 'Combat Process', and to a lesser extent by the 'Attrition Process' and 'Disband Process' (described below). As such, the 'Combat Process' has the greatest impact on an armed force's overall force structure, and the subsequent allocation of resources. This is where the Barbarossa simulation 'commanders' may choose to spend most of their time and effort: possibly attempting to emulate or surpass the historical performance of famous Soviet or Axis commanders.

The resources lost as a result of battle are dependent on the particular land-air combat model used, which in turn employs a whole range of sub-factors. These include factors for Relative Overall Combat Proficiency (ROCP), Supply Distribution Efficiency (SDE), weapon technology, fatigue effects, fortification and terrain effects, and weather conditions.

i. Key Terms and Concepts used in the Combat Process

At this point it is necessary digress and although we will not go into excessive details here, it is very important to distinguish between 'Combat Losses' and 'Operational Attrition Losses'. Refer Volume VI – 'Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces in 1941' for detail on the concepts and terms used in this section. The key

terms used in the ‘Combat Process’ are indicated (below) using ‘single quotes’ and capitals.

‘Combat Losses’ include losses as a result of the ‘Combat Process’ and include:

- **‘Tactical Losses’** , which are defined as all losses sustained as a direct result of enemy fire, enemy ordnance, ‘Close Combat’ or ‘Tactical Surrender’.
- **‘Operational Losses’** , which are defined as all losses sustained as a direct result of ‘Operational Surrender’ and ‘Operational Combat’. Note, land combat units that become isolated from any form of supply, as a direct result of combat, will experience progressively higher levels of ‘Operational Combat’ losses. These type of losses are <u>not</u> classified as ‘Operational Attrition Losses’ (see below), because they occur as direct result of enemy action, albeit delayed.

The reader should note that losses resulting from the combat process <u>do not include</u> **‘Operational Attrition Losses’**: these are covered by the separate ‘Attrition Process’ discussed in the next section.

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In addition, <u>all types</u> of resource losses are characterised as ‘Irrecoverable’ (permanent), or ‘Recoverable’. In this context, irrecoverably lost means lost for the duration of the campaign to the military resources of that side, and not necessarily permanently lost to any post-war society.

‘ **Irrecoverable Losses**’ include:

- Personnel that were killed, missing (killed or captured), permanently unfit and 1/3 of all wounded (those assumed to be badly wounded).
- Equipment that was totally destroyed, abandoned or surrendered.

‘Irrecoverable Losses’ are shown as resources exiting the FILARM model along a dotted line in diagram <u>FILARM</u>. This is symbolised by the

dotted line crossing the enclosed thick-line boundary (i.e. the model's boundary).

' **Recoverable losses**' include:

- Personnel that were 'Lightly Wounded' and 'Wounded'.
- Equipment that was 'Lightly Damaged' and 'Badly Damaged'.

'Recoverable Losses' remain within the integrated resource model. This is symbolised by the resource allocation lines exiting the 'Combat Process' and 'Attrition Process', and returning resources to the 'Campaign Reserves' state. After recovery, repair, etc, these resources may quickly be returned to combat units as 'Replacements (R)' or by entering entirely new combat units (MD and MND combat units).

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ii. Outcomes of the Combat Process

The results of the 'Combat Process' are slightly different for land and air combat units.

Land Combat Units

For land combat units the outcome of the 'Combat Process' will vary as follows:

1. The land combat unit sustains resource losses , and will receive replacements if they are available and depending on priority. This is the usual outcome, with most losses occurring in the combat elements (fighting elements) of the combat unit.

   In this case 'Irrecoverable Losses' leave the FILARM model.

   'Recoverable Losses' are retained by the unit or are reallocated (and physically sent back) to a rear area. 'Campaign Reserves' represent all rear areas.

‘Lightly Wounded’ personnel and ‘Lightly Damaged’ equipment (repaired by the combat unit) are not transferred back to the FILARM model’s ‘Campaign Reserves’. These types of ‘Recoverable Losses’ are manifested as a loss of readiness in the combat unit.

‘Wounded’ personnel and ‘Badly Damaged’ equipment is sent to ‘Campaign Reserves’. This represents equipment such as tanks being sent to the rear area, or even the factory, for major repair; and wounded going to rear area hospitals. This is shown in diagram FILARM by some resources returning directly to the ‘Campaign Reserves’ after the ‘Combat Process’. Ex-wounded and repaired equipment may be returned to the front after a suitable time delay. These resources are not necessarily returned to their original unit, because that unit may have ceased to exist or already have received other replacements to cover its losses. In this case, ex-wounded and repaired equipment becomes part of the overall available resources (i.e. part of the overall ‘Campaign Reserves’).

2. The land combat unit is ‘Totally Destroyed’ and for all practical purposes is wiped out. A combat unit is usually ‘Totally Destroyed’ as a result of an encirclement battle (but not always), sustaining tactical as well as massive operational losses. [93] Losses are experienced in the combat and support elements of the unit: losses will be catastrophic in the fighting elements of the unit (such as its tanks and infantry), as well as supporting infrastructures (such as personnel and trucks in its supply and fuel columns).

   In this case most of the unit’s resources are irrecoverably lost and exit the FILARM model. The unit is removed from the Order of Battle (OOB). The usually small number of recoverable losses is returned to the ‘Campaign Reserves’ immediately. This represents personnel who may escape from a ‘pocket’ due to breakout or infiltration through enemy lines. It should be noted that surviving resources in this situation are nearly always personnel with very little equipment, as this is usually abandoned in the retreat or pocket. A good combat model will ensure most heavy equipment such as tanks and artillery is lost in these situations.

3. The third outcome of the 'Combat Process' is that the land combat unit disintegrates as a cohesive fighting force, usually as a result of heavy losses or being overrun by enemy forces. In military terms this is called 'Shattering', and losses are again usually very heavy in the combat and support elements of the unit.

   Generally, 'Shattering' is difficult to model in military simulations because its results can be extreme. For example, in 1941 several Soviet rifle and tank divisions shattered early in the campaign as they were overrun by German armoured and infantry units. These divisions were still in relatively good supply and had not been cut off from their rear areas. Despite this, these units irrecoverably lost almost all their heavy equipment and most of their personnel. In this case (in the FILARM model) the unit is classified as 'Totally Destroyed'. The reader should note here that 'Being in Supply' is an important condition in determining the likelihood of a unit 'Shattering'.

   During Operation Barbarossa some Soviet combat units shattered but later managed to reorganise and reappear in the Order of Battle (OOB), albeit usually at a considerably reduced strength. However this occurrence was almost always accompanied by large numbers of replacements which were available to effectively rebuild the unit. Shattered combat units were often so badly damaged that it proved more economical to disband the unit, and use the available resources as general replacements and as cadre for new combat units. In some cases this was also probably better for morale: who wants to be assigned to a combat unit that was all but destroyed or with a poor overall record?

   A good land-air combat model simulates the conditions under which a combat unit might shatter. Depending on the type of 'Shattering' and overall situation, a percentage of losses are then classified as 'Recoverable Losses'. [94] In the FILARM model, recoverable resources from shattered units are returned via the 'Disband and Shatter Process' to the 'Campaign Reserves'. This simulates surviving resources from shattered units being withdrawn to the rear area for use as replacements or as cadre in newly mobilised combat units. The

FILARM model, and land-air combat model, also simulate the fact that the surviving resources will contain a greater proportion of heavy equipment (such as tanks and artillery) than in the ‘Totally Destroyed’ conditions described previously.

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Air Combat Units

For air combat units the outcome of the ‘Combat Process’ will vary as follows:

1. <u>The air combat unit sustains resource losses</u>, and will receive replacements if they are available and depending on priority. This is the most common ‘Combat Process’ outcome and all other processes are identical to those for land combat units.

2. <u>The air combat unit is ‘Totally Destroyed’</u> and wiped out. For air units this is relatively rare because most air units are already well to the rear and shouldn’t be overrun quickly. They can fly their serviceable aircraft out of an encircled area and usually have time to get many unserviceable aircraft repaired, at least sufficiently to get them out. Also, most air units have aircraft with spare airlift capacity (especially bomber units) enabling at least a portion of their ground personnel to fly out of danger. However, air units forced to relocate solely by airlift will usually lose most of their heavy ground support equipment. This is usually simulated by the irrecoverable loss of these resources, and the air unit being unable to fly many combat missions for some time.

   Total loss of an air unit can occur as a result of a series of successful air strikes on the air unit’s airfields, accompanied by a rapid encirclement battle trapping the air unit’s ground forces. These conditions were met in the early stages of Operation Barbarossa for many Soviet Military Air Force (*Voyenno-Vozdushnye Sily* or VVS) air combat units in the Western Military Districts. The result was that many Soviet aviation regiments disappeared from the VVS’s Order of Battle (OOB) relatively quickly in 1941. In this case all other processes are identical to those for land combat units.

3. The air combat unit disintegrates as a cohesive fighting force. So called 'Shattering' of air units is rare because of the nature of air warfare. However it can occur if the air unit's airfields are quickly overrun, or exceptionally heavy and successful airfield air strikes are carried out against it. It is more likely that a unit suffering such heavy losses, in the air and on the ground, would be subsequently disbanded. In this case resources from shattered air units that are recoverable are returned via the 'Disband and Shatter Process' to the 'Campaign Reserves'. This represents surviving ground support resources and serviceable aircraft being withdrawn to the rear area for use as replacements or in forming new air units.

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d. The Attrition Process

The 'Attrition Process' is concerned with losses in all combat units, regardless of deployment, due to 'Operational Attrition'. Such losses are referred to as 'Operational Attrition Losses' or simply 'attrition losses'.

'Operational Attrition Losses' are defined as all losses due to training accidents, other accidental loss and scrapping. In addition they are losses due to desertion, disease, sickness and frostbite, which are **unrelated to any 'Tactical Level Combat'** . Therefore **losses resulting from the 'Attrition Process' do not include any type of 'Combat Losses'** (refer above). Note, 'Operational Attrition Losses' are not the same as 'Operational Losses'. The latter occurs as a direct result of enemy action and are a form of 'Combat Losses', albeit often delayed. [95]

Generally it is difficult to accurately simulate attrition losses in a military campaign. This is because attrition losses are largely dependent on the command decisions made during the campaign, similarly to 'Combat Losses'. However attrition losses are additionally influenced by longer term factors such as: the duration and quality of the pre-combat training programmes, the weather, the state of supply and support organisations, the age of equipment, and long term strategic planning.

i. Outcomes of the Attrition Process

The results of the ‘Attrition Process’ are slightly different for land and air combat units.

Land Combat Units

Until the winter of 1941-42, attrition losses in the land forces on the East Front (as opposed to the air forces) were fairly insignificant compared to combat losses, except in the area of motorised transport. Both Axis and Soviet trucks and light transports were predominately civilian types, which broke down frequently on the poor roads. Most of these trucks were repairable, provided the overall offensive or defensive situation allowed the support infrastructures time to do this. [96] Therefore the large majority of vehicle breakdowns (‘Operational Attrition Losses’) were not irrecoverable and only ‘Irrecoverable Losses’ actually exit the FILARM model.

For these reasons ‘Operational Attrition Losses’ in land combat units in the FILARM model are simulated in three ways:

1. The recoverable attrition losses are retained for repair within the land combat unit and these losses are simulated by a loss of combat readiness of the unit. The readiness recovery (or speed of repair) is affected by the operational proficiency for a side, the Supply Distribution Efficiency (SDE), and the overall state of supply to the combat unit at any given time. Thus unserviceable motor vehicles are still listed as on the unit’s strength, but are not immediately usable.

2. If the particular land combat unit moves, a larger proportion of its equipment is lost due to attrition. The attrition losses are affected by: the distance moved, the frequency of movement, the mobility of the unit (e.g. highly motorised or mostly horse drawn), the terrain, the availability and condition of any roads, and the weather. A calculated proportion (usually small) of these lost resources become ‘Irrecoverable Losses’ and exit the FILARM model. Recoverable attrition losses due to movement are simulated by additional unit readiness loss (as above). The more demands that are made on a particular combat unit without a recovery period to consolidate, recover and reorganise, then the higher the attrition losses. The skill of any military commander is to judge how far to push a combat unit

before it wears itself out: push to far and the combat unit becomes very vulnerable to enemy attack and risks ‘Shattering’ in combat. Needless to say, when the winter of 1941-42 arrived the proportion of attrition losses that became ‘Irrecoverable Losses’ rose dramatically.

3. The attrition losses in combat units in a MND state are built into the equipment allocated to these units from ‘Campaign Reserves’. This is necessary because in the FILARM model MND units didn’t see combat in 1941, and are not moved about the battlefield by that side’s Barbarossa simulation ‘commander’ (player). However even though these units never went to an active front in 1941, they still experienced ‘Operational Attrition Losses’, albeit much lower than D and MD combat units.

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Air Combat Units

During Operation Barbarossa, and many other campaigns in WWII, aircraft losses due to ‘Operational Attrition’ were not insignificant compared to ‘Combat Losses’. ‘Operational Attrition Losses’ of aircraft were often severe; particularly training related and other flying accidents which resulted in ‘Irrecoverable Losses’. It is a feature of air warfare that throwing large numbers of inexperienced pilots against even small numbers of excellent pilots is generally a very bad idea. It turns out that one of the principal reasons for this (but not the only reason) is that inadequately trained pilots, thrown prematurely into a combat environment, experience very high numbers of non-combat losses. Land and air warfare are quite different in this regard. This occurs even if the aircraft have similar technical capability, and is greatly exacerbated if the more inexperienced pilots also have inferior or obsolescent combat aircraft.

One of the key differences between land and air warfare is that rushed training programmes, often accompanied by hastily produced aircraft, dramatically raises the number of accidental losses without producing a significant increase in overall combat power. Essentially, if an aircraft breaks down in flight due to rushed quality control or maintenance, or is lost due to aircrew error, then it’s usually a total write-off. Unfortunately the

aircrew are also often lost and the aircraft support crews learn very little. By comparison, if a tank breaks down for the same reasons then it's usually repaired and is a better vehicle, along with a more experienced tank crew and tank support crew. It is relatively difficult for a tank crew to write off a tank by accident! To illustrate this point, between 22nd June and 31st December 1941 the Soviets lost over 26 000 aircraft. [97] Of these, approximately 10 600 were 'officially' non-combat losses. [98] Thus over 40% of the total VVS aircraft losses in 1941 were, apparently, non-combat losses! Of particular note is that of the apparent 10 600 non-combat losses, 7 600 were front line combat aircraft and not (more expendable) training aircraft. [99]

Accurately simulating the VVS's 'Operational Attrition Losses' in 1941 is tricky because the Soviets could have reduced their losses by making different operational and strategic command decisions. By reducing the number of inexperienced air combat units thrown into the front line, and hence increasing the training time, the VVS would have almost certainly reduced its 'Operational Attrition Losses'. This operational-strategic level command decision would not have increased the factory quality control and testing of new aircraft, but it would have given air units more time to iron out problems with new aircraft in the field before committing them to combat.

The two practical ways available to simulate aircraft 'Operational Attrition Losses' are to only issue combat aircraft that 'survive training' to front line air combat units, or build 'Operational Attrition' into the operational proficiency and readiness of all air combat units. I believe the latter is the superior model because it enables different operational decisions to influence the air-land campaign, as opposed to the Soviets simply 'losing' 7 600 combat aircraft even if they never fly a single combat mission. By adopting the second model the VVS air units also have the ability to increase their operational proficiency over time, provided the Soviet simulation 'commander' gives them time to do this (which the Stavka and VVS High Command generally didn't do in 1941).

For these reasons 'Operational Attrition Losses' in air combat units in the FILARM model are simulated in three ways:

1. The recoverable attrition losses are retained for repair within the air combat unit, and these losses are simulated by a loss of combat readiness of the unit. The readiness recovery (speed of repair) is affected by the operational proficiency for a side, the Supply Distribution Efficiency (SDE), and the overall state of supply to the combat unit at any given point in time. Thus unserviceable aircraft are still listed as on the unit's strength, but are not immediately usable.
2. The irrecoverable attrition losses are simulated by the unavailability of the air combat unit to carry out combat missions. This is controlled by the operational proficiency values for a side, and represents time spent in training and loss of combat capability as a direct result of irrecoverable attrition losses. Thus a low proficiency air unit may become unavailable for operations even in a rear area were it wasn't involved in direct combat. The lower the operational proficiency, the more likely the unit will become unavailable for combat, even after relatively few combat missions. The opposite effect occurs for high proficiency, highly trained units.
3. The attrition losses in air combat units in a MND state are built into the equipment allocated to these units from 'Campaign Reserves'.

***

e. The Disband and Shatter process

The 'Disband and Shatter Process' is grouped together because 'Shattering' and disbandment of combat units is similar. The difference between the two is essentially the proportion of recoverable resources that occur. In the shatter case, the number of recoverable resources varies widely, while in the disband case the vast majority of resources are usually recoverable.

i. Combat Unit Shattering

A shattered unit <u>only</u> arises as a direct result (outcome) of the 'Combat Process'.

In this case the unit is shattered regardless of any higher command decisions, and the severity of shattering is calculated by the combat model and combat conditions at the time. [100] In the worst cases of combat unit shattering relatively few resources will be recovered, but in the best cases the majority will survive to be reused. The combat unit's readiness, supply state and Relative Overall Combat Proficiency (ROCP) when it shatters, are factors used in determining the proportion of the unit's resources that become 'Recoverable Losses'. All 'Recoverable Losses' from shattered units are reallocated to the 'Campaign Reserves', while all 'Irrecoverable Losses' exit the FILARM model from the 'Combat Process'.

A shattered unit's 'Recoverable Losses' are represented in diagram FILARM by recoverable resources entering the 'Disband and Shatter Process' from the 'Combat Process', and then being reallocated to 'Campaign Reserves'.

ii. Combat Unit Disbandment

Disbandment of combat units only occurs as a result of a higher command decisions, and thus the 'Disband Process' is more complex and applies in several situations.

Combat units that go through the 'Disband Process' are categorised as follows:

1. The combat unit is in such poor condition as a result of combat that a command decision is made to disband it, and use the surviving resources as replacements and for newly mobilising units.

   This is represented in diagram FILARM by resources being reallocated from a D or MD combat unit, via the 'Attrition Process' and the 'Disband and Shatter Process', and into 'Campaign Reserves'. Note, the resources in this case are not reallocated via the 'Combat Process' because the unit survived the combat as a cohesive force and was disbanded by a command decision. The combat unit could have been withdrawn to a rear area to rebuild by a different command decision: in which case it would have remained a D or MD unit in the rear area and received 'Replacements (R)'.

2. The combat unit was historically never committed to combat with its original TOE, no longer conformed to current requirements, and a command decision was made to wholly or partially disband the unit and utilise its resources.

   In this case of unit disbandment, the unit may initially be in a D, MD, or MND state and may not conform to current requirements for any number of reasons. These may include: being organised using a TOE structure that is no longer supported or usable, the unit may not be able to get sufficient recruits from its local recruitment area to achieve an adequate strength, or the unit is serving no useful purpose in a secondary theatre and it is easier to disband it rather than move the entire unit. It is considered that some attrition of resources would occur in all these cases. This is represented in diagram FILARM by resources being reallocated from a D, MD or MND combat unit, via the ‘Attrition Process’ and the ‘Disband and Shatter Process’, into ‘Campaign Reserves’.

   A historical example is the Soviet 6th Tank Division (classified as a Deployed (D) unit) in the Transcaucasus Military District on 22nd June 1941. It was disbanded in September 1941, having never seen combat and never having left its formation area, even though it had 348 tanks and tankettes on strength. [101] Most of the resulting resources were reallocated as replacements for other tank units, while some went into the new 6th Tank Brigade (a new Mobilised and Deployed (MD) unit). Thus all the 6th Tank Division’s resources were reallocated via the ‘Attrition Process’ and the ‘Disband and Shatter Process’, and into the ‘Campaign Reserves’

   In some cases only a portion of the combat unit was disbanded. For example, the Soviet 58th Tank Division was partially disbanded in late July 1941 in the Far Eastern Front when it was reorganised from the pre-war TOE (*Shtat*) to the smaller July 1941 TOE. In this case approximately 180 tanks and tankettes were released for other combat units. [102]

3. The combat unit was historically committed to combat. Subsequently, the unit was disbanded with the specific plan of reallocating all of its resources and part of its initial TOE structure to form a (so called) new combat unit.

   In this case the combat unit is officially disbanded by renaming it as a 'new' unit, and usually (but not always) adding additional resources from reserves. The disbanding unit may initially be an existing unit from 22nd June 1941 (i.e. a Deployed (D) unit), or it may be a newly mobilised unit. Note, however, that after undergoing the 'Disband and Shatter Process' a unit can only ever be reclassified as a MD or MND unit: i.e. once an existing Deployed (D) unit is disbanded, any new unit created from its resources is considered a newly mobilised unit. It is considered that some small attrition of resources would occur in all these cases.

   This procedure is almost entirely (and extensively) utilised by the Soviet FILARM model, where it is discussed in detail. [103] This is because the massive Soviet mobilisation programme in 1941 called for a large number of existing divisions to be renamed and reformed as 'new' divisions. The complete sequence of processes and resource reallocation is represented in diagram FILARM as follows. Resources are reallocated from units in a D, MD or MND state, via the 'Attrition Process' and the 'Disband and Shatter Process' to the 'Campaign Reserves' state. Then the resources are reallocated, via the 'Check the TOE Authorisation of a MD or MND Unit Process', to the newly mobilised (renamed in reality) combat unit.

   For example, consider the case of the Soviet 131st Mechanised Division in the Kiev Special Military District on 22nd June 1941. After a short period in combat, it was redesignated the 131st Rifle Division on 3rd July 1941. The only truly new component in the 'new' 131st Rifle Division was the 743rd Rifle Regiment, which was added from reserves. [104] Soviet mechanised divisions normally had two motorised regiments, a tank regiment and an artillery regiment. New rifle divisions in July 1941 had three infantry regiments and an artillery regiment. Thus by replacing the tank regiment with a rifle

regiment, and a reduction in motorisation, a ‘new’ rifle division was formed. As the 131st Mechanised Division’s tank regiment had virtually ceased to exist by July 1941 (due to combat losses), and the division started the war with only 595 trucks and 69 tractors, this conversion was pretty easy to do and was largely a paper exercise. [105]

In this example the 131st Mechanised Division starts as a Deployed (D) unit which experienced considerable ‘Irrecoverable Losses’ via the ‘Combat Process’. However the unit did not shatter in combat, was never ‘Totally Destroyed’, and remained a relatively strong and cohesive combat unit. On 3rd July a command decision caused the unit to be effectively disbanded with the plan to utilise all its resources to form the so called new 131st Rifle Division. Thus all the 131st Mechanised Division’s resources were reallocated via the ‘Attrition Process’, the ‘Disband and Shatter Process’, the ‘Campaign Reserves’, the ‘Check the TOE Authorisation of a MD or MND Unit Process’, and into the ‘new’ 131st Rifle Division. Note that these resources were reallocated only, and not necessarily physically moved, in order to become part of the ‘new’ division. Simultaneously the new 743rd Rifle Regiment, formed from ‘Mobilised Personnel’ entering the FILARM model and going into ‘Campaign Reserves’, was allocated to the ‘new’ division. Therefore, apart from some Replacements (R), the only genuinely new resources that were used in forming the ‘new’ 131st Rifle Division were those in a single new rifle regiment.

In many Operation Barbarossa simulations (and accounts of the campaign) the 131st Rifle Division appears as a completely new rifle division at virtually full strength. Even worse, the 131st Mechanised Division continues in the line! This very significant error is often repeated for many ‘new’ Red Army divisions mobilised from June to December 1941.

***

One of the great benefits of the FILARM model is that it enables military simulation designers to avoid unrealistic and ahistorical results of the type described above. This is critical if the military simulation is

striving to achieve historical accuracy, and produce a realistic analysis of probable alternative historical outcomes. The three disbandment scenarios described above, and the overall structure of the FILARM model, are all geared towards this objective. Equally important for historical accuracy, is that the 'Shatter and Disband Process', and its implementation in the FILARM model, allows the simulation 'commander' (player) to have the same operational freedom of action as the historical protagonists. [106]

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[72] Refer to Volume I, Part I 3. 4) e. ii. – 'The Structure of the Fully Integrated Land and Air Resource Model (FILARM) - Combat Unit Processes inside the FILARM Model - Disband and Shatter process - Combat Unit Disbandment' for details. This procedure is almost entirely (and extensively) utilised by the Soviet FILARM model, where it is discussed in detail. This is because the massive Soviet mobilisation programme in 1941, called for a large number of existing divisions to be renamed and reformed as 'new' divisions. Also refer to Volume III - 'The Soviet Armed Forces, Mobilisation and War Economy from June to December 1941', chapter title 'Soviet Mobilisation After 22nd June 1941: The Actual Strength of all Soviet Land Combat Units Mobilised from 22nd June to 31st December 1941'.

[73] For example, Volumes IIB and IIIA, chapters titled 'The Order of Battle (OOB) of German Land Combat Units from 22nd June to 4th July 1941' and 'The Order of Battle (OOB) of Soviet Land Combat Units on 22nd June 1941', respectively, contain the Deployment Matrices of German and Soviet ground forces. Similar, but separate, Deployment Matrices' are present for the respective air-forces.

[74] Refer to Volume IIIB, chapters titled 'Soviet Mobilisation After 22nd June 1941: The Actual Strength of all Soviet Land Combat Units Mobilised from 22nd June to 31st December 1941' and 'The Soviet Air Forces in 1941 - Soviet Air Combat Unit Reinforcements: June 1941 to January 1942', for details on Soviet land and air combat units Mobilised and Deployed (MD) in 1941.

[75] Refer to Volume IIB, chapters titled 'German Mobilisation After 22nd June 1941: the Actual Strength of German Land Combat Units Mobilised from 22nd June to 31st December 1941' and 'The Luftwaffe in 1941 - Luftwaffe Air Combat Unit Reinforcements: June to December 1941' for details on German land and air combat units Mobilised and Deployed (MD) in 1941.

[76] Ibid (previous two notes), for details on all Soviet and German land and air combat units Mobilised and Not Deployed (MND) in 1941. Also, it should be carefully noted here that all D, MD and MND combat units may still receive newly mobilised personnel and equipment (i.e. reserve forces) via the Replacement (R) process. In the FILARM model the **Replacement (R) process is a separate process to creating completely new combat units.** In this way combat units which are considered newly mobilised but were in fact merely old units with a simple name change, can still build up their strength to their TOE, given enough time and priority treatment.

[77] For example, the 131st Rifle Division started forming on the 3rd July 1941. It was quickly formed by redesignating the existing pre-war 131st Mechanised Division as a rifle division, and adding the new 743rd Rifle Regiment from reserves. This was the only truly new component of the so called

“new 131st Rifle Division”. In this case the 131st Rifle Division is still a MD unit, but it arrives (i.e. is Deployed (D) on the battlefield) with only the 743rd Rifle Regiment: the remainder of the division in the Barbarossa simulation comes from the remnants of the pre-war 131st Mechanised Division, as occurred historically. In effect, 1/3 of the 131st Rifle Division is classified as MD, while 2/3s is classified as MND.

[78] An example is the 427th Rifle Division. This unit started mobilising in December 1941 whilst in the Moscow region. The 427th was still mobilising (forming) on 2nd January 1942 when it was redesignated the 149th Rifle Division. It was not assigned to an active army (the 61st Army) till February 1942. Considering the state of many new units assigned to ‘Active Fronts or Armies’ and committed to combat by the Red Army in 1941, this type of MND unit must really have been in an early state of formation and training. However these units still consumed resources, although relatively few, in 1941.

[79] Refer to Volume I, Part I 8. - ‘Supply Distribution Efficiency (SDE)’ for details on how SDE is calculated.

[80] C. C. Sharp, ‘Red Legions’: Soviet Rifle Divisions Formed Before June 1941, Soviet Order of Battle WWII: Volume VIII, George F. Nafziger, West Chester, OH, 1996, p.5.

[81] D. M. Glantz, Stumbling Colossus, University Press of Kansas, Lawrence, Kansas, 1998, pp. 110-116.

[82] C. C. Sharp, ‘Red Legions’: Soviet Rifle Divisions Formed Before June 1941, Soviet Order of Battle WWII: Volume VIII, George F. Nafziger, West Chester, OH, 1996, p.105, Also D. M. Glantz, Stumbling Colossus, University Press of Kansas, Lawrence, Kansas, 1998, p. 111 and Table 5.2, p. 152.

[83] D. M. Glantz, Stumbling Colossus, University Press of Kansas, Lawrence, Kansas, 1998, note 11, p.298.

[84] The 209th Assault Gun Battalion arrived after 31st December 1941. The 249th Assault Gun Battalion remained in the West.

[85] H. Boog, et al. (German Research Institute for Military History at Potsdam), Germany and the Second World War, Volume IV: The Attack on the Soviet Union. Oxford University Press, New York, 1996, p. 219, table I.iii.4, and pp. 1120 and 1122. Also, P. Chamberlain, H. Doyle, T.L. Jentz, Encyclopedia of German Tanks of WWII, Arms and Armour Press, London, 1994, appendices VII, p. 261. Also, refer to Volume II (the German FILARM model) for further details.

[86] Refer to Volume I, Part I 6. – ‘Tables of Organisation and Equipment (TOE)’.

[87] Refer to Volume IIIA, chapter and section titled ‘The Actual Strength of all Soviet Land Combat Units in a Deployed (D) State on 22nd June 1941 - Review of the Overall Strengths of Selected Red Army Units and PVO forces on 22nd June 1941 - The Mechanised Corps’, for a summary of the Red Army’s mechanised corps actual strengths in June 1941 compared to their TOEs. Many mechanised corps were mere skeletons of much larger organisations, and were still barely formed.

[88] Many mechanised divisions were redesignated as rifle divisions by adding a rifle regiment from reserves. This created the three rifle regiments normally attributed to a rifle division. In most ‘converted’ mechanised divisions, the division’s tank regiment and most of the motorisation either never existed or had been wiped out by July 1941.

[89] S. J. Zaloga, L . S. Ness, Red Army Handbook 1939-1945, Sutton Publishing, Stroud, UK, 1998, pp. 70-74. Also, C. C. Sharp, 'The Deadly Beginning': Soviet Tank, Mechanised, Motorised Divisions and Tank Brigades of 1940-1942, Soviet Order of Battle WWII: Volume I, George F. Nafziger, West Chester, OH, 1995, pp. 15, 51, 93.

[90] S. J. Zaloga, L . S. Ness, Red Army Handbook 1939-1945, Sutton Publishing, Stroud, UK, 1998, pp. 13-15.

Also, C.C. Sharp, 'Red Tide': Soviet Rifle Divisions Formed From June to December 1941, Soviet Order of Battle World War II: Volume IX, George F. Nafziger, West Chester, OH, 1996, pp. 118-121.

[91] S. J. Zaloga, L . S. Ness, Red Army Handbook 1939-1945, Sutton Publishing, Stroud, UK, 1998, p. 37. Also, C. C. Sharp, 'Red Volunteers': Soviet Militia Units, Rifle and Ski Brigades 1941-1945, Soviet Order of Battle WWII: Volume XI, George F. Nafziger, West Chester, OH, 1996, pp. 96-97.

[92] It should be noted that when a combat unit is created with a particular TOE, it does not change its structure for the duration of the campaign (i.e. up to the end of 1941). Therefore, in the Barbarossa simulation Replacements (R) are issued to a combat unit according to the original TOE used in its formation.

[93] In WWII this was relatively uncommon on the Western Front, especially for divisional sized combat units, (examples were the surrender of Axis forces in North Africa, and in Germany in 1945). However, the almost complete destruction of whole divisions was not uncommon on the East Front from 1941 to 1945. Many Soviet corps, and even entire armies, were 'Totally Destroyed' during Operation Barbarossa in 1941.

[94] For example, the readiness and supply state of a combat unit that is overrun (and shatters) will be generally proportional to the amount of recoverable resources.

[95] Refer to Volume VI – 'Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces in 1941' for further definition and explanation of these terms and concepts.

[96] The reader should note that for many Red Army units in the Western Military Districts in June-July 1941, breakdown of any tank, truck or similarly motorised equipment was usually fatal (eventually became an irrecoverable loss). This was because of the speed of the German encircling operations, which were moving eastwards faster than many Red Army units could retreat (even if they had been immediately ordered to do so). This left no time for Red Army unit to repair many of these vehicles before they were overrun or encircled.

[97] C. Bergstrom, A. Mikhailov, Black Cross Red Star: Air War Over the Eastern Front Volume I, Pacifica Military History, Pacifica, California, 2000, p. 252. 21 200 aircraft lost in official figures plus 5 240 "unaccounted for decrease in VVS strength" between 22nd June and 31st July 1941. Also refer to Volume IIIB, chapter and section titled – 'The Soviet Air Forces in 1941- Overall Soviet Combat Aircraft Usage, Production and Replacements (R): 22nd June to 31st December 1941- Review of the VVS Aircraft Losses in 1941', for further analysis of these figures.

[98] G. F. Krivosheev, et al, Soviet Casualties and Combat Losses in the Twentieth Century, ed. Colonel General G.F. Krivosheev, Greenhill Books, London, 1997, p. 254, table 95.

[99] Ibid. There is strong evidence that Krivosheev's figure for non-combat losses is much too high. It seems very improbable that 72% of non-combat losses were front-line aircraft and only 28% were trainers or transports. Considering that Krivosheev's figures also ignore the 5 240 "unaccounted for decrease in VVS strength" between 22nd June and 31st July 31st, and the discrepancy between

Krivosheev figure for total combat losses (10 600 in 1941) and Luftwaffe claims (around 20 400 by the end of 1941), it seems very likely a much larger proportion of “non-combat losses” were actually combat losses. Also refer note 97 (above).

[100] Refer to the ‘Combat Process’ above. Also Volume VI for the requirements of the combat model in a Barbarossa simulation.

[101] Refer Volume III, chapter and section titled – ‘The Actual Strength of all Soviet Land Combat Units in a Deployed (D) State on 22nd June 1941 - The Soviet Tank Deployment Matrix’. Also, C. C. Sharp, ‘The Deadly Beginning’: Soviet Tank, Mechanised, Motorised Divisions and Tank Brigades of 1940-1942, Soviet Order of Battle WWII: Volume I, George F. Nafziger, West Chester, OH, 1995, pp. 21 and 71.

[102] Ibid, Volume III. The 58th Tank Division was subsequently committed to combat in the West in October 1941, but not with its original TOE from 22nd June 1941. Also, C. C. Sharp, ‘The Deadly Beginning’: Soviet Tank, Mechanised, Motorised Divisions and Tank Brigades of 1940-1942, Volume I, George F. Nafziger, West Chester, OH, 1995, p. 45.

[103] Refer to Volume IIIB, chapter titled ‘Soviet Mobilisation After 22nd June 1941: The Actual Strength of all Soviet Land Combat Units Mobilised from 22nd June to 31st December 1941’.

[104] C.C. Sharp, ‘Red Tide’: Soviet Rifle Divisions Formed From June to December 1941, Soviet Order of Battle WWII: Volume IX, G. F. Nafziger, West Chester, OH, 1996, p. 20.

[105] C.C. Sharp, ‘The Deadly Beginning’: Soviet Tank, Mechanised, Motorised Divisions and Tank Brigades 1940-1942, Soviet Order of Battle World War II Volume 1, G. F. Nafziger, West Chester, OH, 1995, p. 59.

[106] Refer to Volume I, Part I 2. 2) g. - ‘The Integrated Land and Air Resource Model - The Objectives of the Integrated Land and Air Resource Model - Operational Freedom of Action (within the simulation)’, for additional perspectives on this topic. Also refer to Volume IIIB, chapter titled ‘Soviet Mobilisation After 22nd June 1941: The Actual Strength of all Soviet Land Combat Units Mobilised from 22nd June to 31st December 1941’.

4. The Structure of the Partially Integrated Land and Air Resource Model (PILARM)

For the Partially Integrated Land and Air Resource Model (PILARM), the underlying principle of conservation of resources is unchanged. The main difference between the FILARM and PILARM models is that in the latter the boundaries of the model, or 'system', are reduced. In the PILARM model only the resources allocated to the ' **East Front forces**' are included, and not all the armed forces of a particular country.

In the context of the PILARM model, 'East Front' is defined as territory in the Soviet Union (as set by the borders on 1st June 1941). In addition 'East Front forces' are defined as forces which entered the Soviet Union on or after 22nd June 1941, and forces which were made available to the relevant command to enter the Soviet Union after 22nd June 1941 (even if they never actually entered the Soviet Union).

The general structure of the Partially Integrated Land and Air Resource Model is shown in the resource allocation flow diagram shown in diagram PILARM. The partially integrated model consists of the following components:

i. A model representing all resources present at the start of the campaign which were allocated to the 'East Front' forces, and all resources received on the East Front from all sources during the campaign (symbolised by the enclosed thick-line boundary). Refer below for definition of 'East Front' in this context.

ii. 2 resource sources and 1 resource destination, outside the model (dashed-line bordered boxes).

iii. 2 paths by which resources can physically enter the model (dotted lines).

iv. 2 paths by which resources can physically exit the model (dotted lines).

v. 15 lines and directions by which resource reallocation can occur within the model (solid lines).

vi. 5 ‘ **resource allocation states**’ inside the model, made up of:

- Deployed (D) Combat Units and Reinforcements (grey filled boxes).
- Supply and Support Infrastructure (a dot filled box).
- Replacements (R) and Front Campaign Reserves (dashed-line filled boxes).

vii. 5 ‘ **combat unit processes**’ (blank boxes). Combat units must undergo one or more of these processes in order for any resources to be reallocated to combat units within the model, or for any resources to leave the model as irrecoverable losses.

The concepts, components, terms and processes used in the PILARM model (and illustrated in diagram <u>PILARM</u>) are identical to the FILARM model, <u>except</u> for the key areas detailed below.

***

General Structure of the Partially Integrated Land and Air Resource Model (PILARM)

General Structure of the Partially Integrated Land and Air Resource Model: (PILARM)

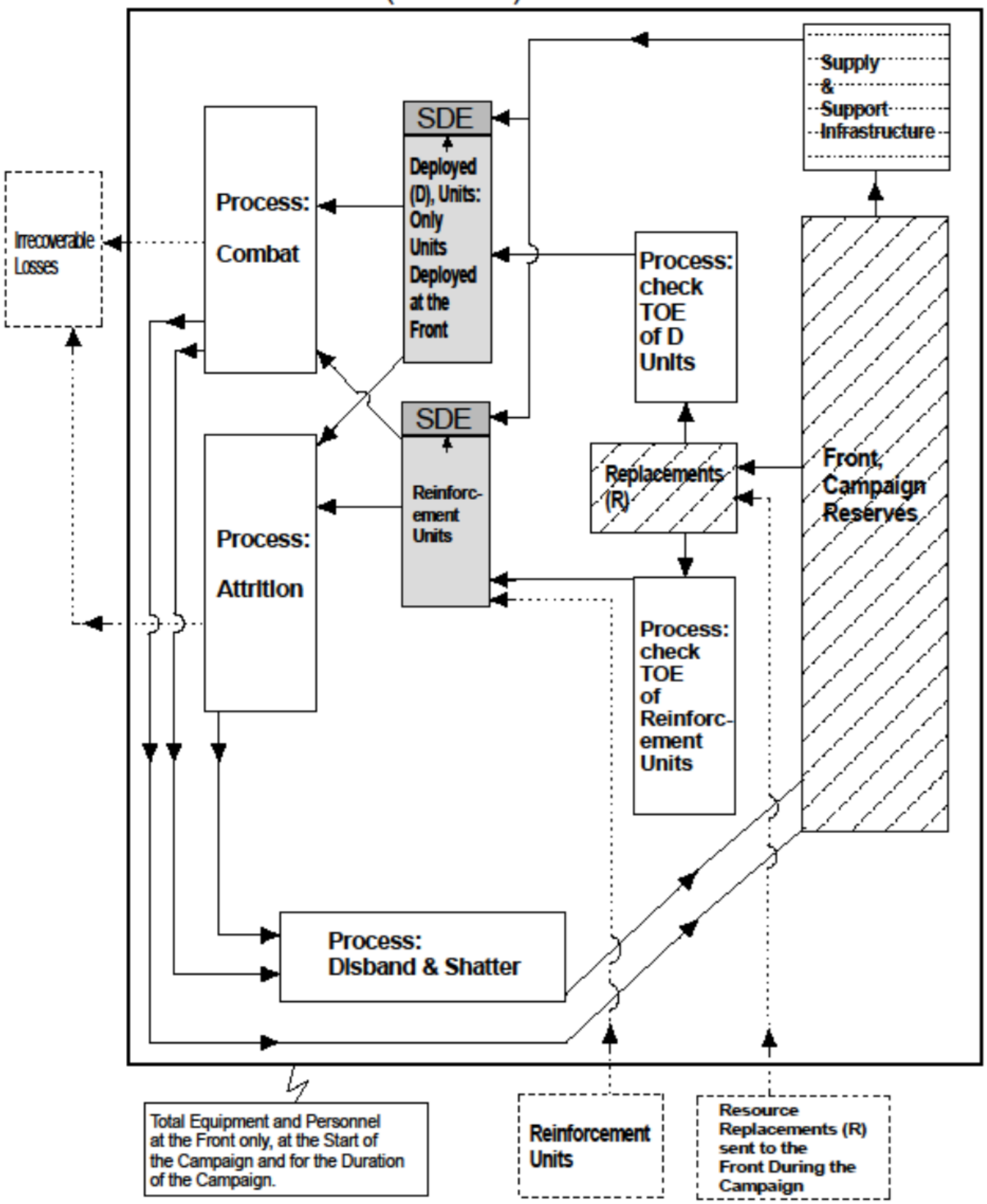

Fig PILARM

1) Resource Sources, Destinations and Paths outside the PILARM Model

The thick-line boundary

The enclosed thick-line boundary in diagram PILARM represents the partially integrated resource model's limits. All resources present at the start of the campaign which were allocated to the 'East Front forces', and all additional resources received by the East Front forces from all sources during the campaign period, are within the model.

In the context of the PILARM model, 'East Front forces' are defined as forces which entered the Soviet Union on or after 22nd June 1941, and forces which were made available to the relevant command to enter the Soviet Union after 22nd June 1941 (even if they never actually entered the Soviet Union).

The thick-line boundary still conceptually represents the conservation of physical mass, with the 'mass' in this case being that country's resources committed to the East Front. The only way this can increase or decrease is by resources entering (i.e. new resources) or exiting the model (i.e. irrecoverable losses) along one of the dotted lines (refer below).

The dashed-line bordered boxes

The dashed-line bordered boxes in diagram PILARM represent resource sources and losses. All new resources must come from 'Replacements (R)' allocated specifically to the East Front after 22nd June 1941, or from combat units sent to the East Front after 22nd June 1941 as 'Reinforcement Units'.

The PILARM model is not concerned with a country's total mobilisation or bottlenecks in the mobilisation process, as these occur outside the boundaries of the model. Therefore historical Replacements (R) are still used, but no effort is made to analyse these as a proportion of the overall replacements available in that country. Similar criteria apply to MD and MND combat units as defined in the fully integrated model: the mobilisation of new combat units occurred in the rear area of the country in

question, which is also outside the East Front boundary limits in the PILARM model. Therefore reinforcements can only come from:

- Existing combat units which were Deployed (D) on 22nd June 1941 outside the East Front boundary (as defined above), and which transferred to the East Front after that date.
- Combat units which were mobilised after 22nd June 1941 and which historically transferred to the East Front after that date.

The losses box and all loss types are identical to the FILARM model.

The dotted lines

The dotted lines in diagram P ILARM represent resources entering and exiting the model.

Resources cannot be created, unless they enter the model as 'Replacements (R)' or as 'Reinforcement Units' for the East Front.

Resources cannot disappear (cease to exist), unless they exit the model via the 'Combat Process' or 'Attrition Process', as 'Irrecoverable Losses'.

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2) Resource Allocation States inside the PILARM Model

As stated previously, there are five possible 'Resource Allocation States' inside the PILARM model made up of: 'Deployed (D) units', 'Reinforcement Units', 'Supply and Support Infrastructure', 'Replacements (R)' and 'Front Campaign Reserves'. The D and 'Reinforcement Unit' states are 'combat capable' states and units in these states are therefore referred to as 'combat units'.

a. Combat Units: D and Reinforcement Units

The two grey filled boxes represent the combat units within the 'East Front forces', to which resources are allocated. The East Front forces include army, air force (including naval air), militia, rear area support, and

naval personnel seconded to the army. All combat capable organisations (or combat units) in the armed forces have a TOE regardless of size. They are specifically categorised into one of the following:

i. Deployed (D)

The combat unit is deployed with a TOE, and assigned to the 'East Front forces', on the first day of the campaign, in this case 22nd June 1941. The unit may be deployed at a fraction of its full TOE strength. 'East Front forces' are defined as forces which entered the Soviet Union on or after 22nd June 1941, and forces which were made available to the relevant command to enter the Soviet Union after 22nd June 1941 (even if they never actually entered the Soviet Union).

The Axis allies had substantial forces deployed in support of Operation Barbarossa, even though they didn't attack immediately. These included the Finnish Karelia Army, the Rumanian Army Group Antonescu, the Hungarian Carpathian Army Group and the Slovak 1st Field Corps. All units in these forces were committed to Operation Barbarossa up to 4th July 1941, and are considered Deployed (D) on 22nd June 41.

The details and assignments of all units in a Deployed (D) status are detailed in the **Deployment Matrices** for each of the Axis allied countries using the PILARM model. [107] There is a separate Deployment Matrix for each of the land, air and naval forces involved.

ii. Reinforcement Units

The combat unit is transferred to the East Front forces with a TOE after the 1st day of the campaign, in this case 22nd June 1941, and assigned to an active corps or army HQ. For Hungary, Rumania, Slovakia and Italy, an 'active corps or army HQ' is any corps or army HQ assigned to the East Front forces.

The reinforcing unit may be an existing unit on 22nd June 1941 which transferred to the East Front after that date, or a unit mobilised after 22nd June 1941 and which transferred to the East Front forces after that date.

***

b. Reserves and Replacements (R)

The three dashed-line filled boxes in diagram PILARM represent reserves in the armed forces to which resources are allocated. Reserves in the armed forces may or may not have a TOE, and are not directly combat capable. They are specifically categorised into one of the following:

i. Replacements (R)

'Replacements (R)' are personnel and equipment that were historically allocated to replace losses in combat units on the East Front in the second half of 1941.

The combat units may be D units or 'Reinforcement Units', and the PILARM model will allocate Replacements (R) according to the currently authorised TOE and operational priority. A unit may be below TOE strength due to loss of resources from combat, training and rear area attrition, or scrapping. Alternatively, it may be below TOE strength in its initial peacetime deployment and require newly mobilised resources to bring it up to full strength in time of war.

ii. Front Campaign Reserves

'Front Campaign Reserves' are resources available to the East Front forces, and which were not allocated to any unit in a D state at the start of the campaign. 'Front Campaign Reserves' may only be committed as Replacements (R), or as additional resources for 'Supply and Support Infrastructure', during the campaign.

Note that in the PILARM model a Deployed (D) unit is a unit with a TOE anywhere on the East Front on the first day of the campaign, and not anywhere in that country's armed forces (as in the FILARM model). Therefore 'Front Campaign Reserves' does not include resources allocated to units deployed in that country's home territory or other fronts in Western Europe.

During the campaign, resources are only received into 'Front Campaign Reserves' as recoverable losses from the 'Combat Process' and the 'Disband and Shatter Process'.

***

3) Combat Unit Processes inside the PILARM Model

In diagram PILARM, the blank boxes represent 'Combat Unit Processes'. Combat units must undergo one or more of these processes for any resources to be reallocated within the model, or for any resources to leave the model (as irrecoverable losses).

Almost all the 'Combat Unit Processes' in the PILARM model can be viewed as identical to those in the fully integrated (FILARM) model. The only exception to this is the 'Check the TOE Authorisation of a MD or MND Combat Unit' process in the FILARM model, which is removed and replaced with the following:

a. Check the TOE Authorisation of a Reinforcement Combat Unit

The process will check whether a particular 'Reinforcement Unit' is authorised to receive a Replacement (R) resource, based on any currently active TOE, before allocating the resource. The TOEs used in this case include those issued before 22nd June 1941 for Deployed (D) units, and TOEs issued after 22nd June 1941 for newly mobilised units.

After 22nd June 1941 several new unit types (with new TOEs) were mobilised by the Axis allies and sent to the East Front. Examples include the Hungarian security brigades which were mobilised in Hungary after June 1941 and which were dispatched to the East Front in September 1941. Other examples include the Rumanian security divisions formed in Rumania in September 1941 with new TOE structures. They were then sent to the East Front in October 1941 as reinforcements.

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All other partially integrated model (PILARM) components are identical to those in the fully integrated land and air model (FILARM) .

***

[107] Refer Volume IV.

5. The Order of Battle (OOB): the Force Deployment Matrices

For each of the combatants in Operation Barbarossa there are three Deployment Matrices: one each for the land, air and naval forces. A **Deployment Matrix** includes all combat units defined as Deployed (D) in the FILARM and PILARM models in June 1941.

In the FILARM model a combat unit is defined as Deployed (D) if it is deployed with a TOE anywhere in the armed forces on the first day of the campaign, in this case 22nd June 1941. The unit may be deployed at a fraction of its full TOE strength and it may be allocated to any military district or army. [108]

In the PILARM model a combat unit is defined as Deployed (D) if it is deployed with a TOE, and assigned to the 'East Front forces', on the first day of the campaign, in this case 22nd June 1941. The unit may be deployed at a fraction of its full TOE strength. 'East Front forces' are defined as forces which entered the Soviet Union on or after 22nd June 1941, and forces which were made available to the relevant command to enter the Soviet Union after 22nd June 1941 (even if they never actually entered the Soviet Union). [109]

***

In this context 'combat unit' means combat capable, which doesn't mean it's was necessarily a good idea to put the unit in the front line. It may have been capable of limited direct combat but its principal function may have been far more important. For example, the unit may have been a bridging engineer battalion or any one of a multitude of HQ unit types. The most important thing is all combat units had an official Table of Organisation and Equipment (TOE) (refer next entry). For naval forces the 'combat unit' is represented by individual ships and gunboats, down to patrol and escort vessels.

The Deployment Matrices include the following properties:

- The land combat unit Deployment Matrices details the corps, army and military district (or front) assignments for all Soviet forces; and the corps, army and army group assignments for all Axis forces.
- The Deployment Matrices for land and air forces are different in the fully and partially integrated land and air models. In the full land and air model (FILARM), all the country's combat units are listed for June 1941 with all combat command organisations in all locations. In the partial model (PILARM) all the country's combat units are listed for June 1941 for all combat units in the East Front forces only.
- The Deployment Matrices for a particular country lists the command organisations present in that country's land and air forces along the x (horizontal) axis. Along the y (vertical) axis are all the combat unit types that existed in that country's land and air forces.
- In the Soviet land combat unit Deployment Matrices, the columns represent military districts or fronts broken down into numbered armies. [110] Mechanised corps and rifle corps are then shown as units in the relevant army.
- In the Axis land combat unit Deployment Matrices, the columns represent army groups, broken down into armies, and then further broken down into corps. [111]

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The table below is an example of the 'German Deployment Matrix' for the German 16th Army in Army Group North on 22nd June 1941.

Table German Deployment Matrix	Deployment and Composition of the German Army, Waffen SS and Luftwaffe Flak Units, 22nd June 1941							
	Army Group North							
	16th Army							
	X Corps		**XXVIII Corps**		**II Corps**		**Army Reserve**	
	Description	**No**	**Description**	**No**	**Description**	**No**	**Description**	**No**
Army & Panzer Group HQs								
Army HQs							16	1
Corps HQs	10	1	28	1	2	1		
Panzer Corps HQs								
Army Group Rear Area HQs								
Army & Army Grp Signal Regs							501	1
Army & Army Grp Signal Batts								
Panzer Group Signal Regs								
Infantry Divisions	30, 126	2	122, 123	2	12, 32, 121	3	253	1
Panzer Divisions								
Motorised Divisions								
SS Motorised Divisions								
Cavalry Divisions								
Mountain Divisions								
Light Divisions								
Fleiger Divisions								
Motorised Infantry Brigades								
Motorised Infantry Regiments								
Motorised Infantry Battalions								
(Mixed) Infantry Regiments								
(Mixed) Infantry Battalions								
Tank Brigades								
Tank Battalions								
Cavalry Regiments								
Security Divisions or Brigades								
Guard (*Wach*) Battalions							(562, 615)**	2
Landesschutzen Battalions								
Artillery HQs, *Harko* & *Arko*	24, 135	2	19, 130	2	105, 111	2		
Art Observation Battalions	38	1	19	1	5, 14^	2		
Artillery Reg HQs (Spec P)	785	1	610	1	603, 782, 803	3		
Mixed Artillery Battalions					I./106	1		
150mm How Battalions	846, 850	2	II./47, 843	2	506, 526	2		
105mm Gun Battalions	I./818	1	153	1	II./72	1		
150mm Gun Battalions							625	1
210mm How Battalions (1)					636, 809	2		
210mm How Battalions (2)								
210mm Gun Battalions								
Hvy 240mm How Battalions								
Hvy 240mm Gun Battalions							II./84	1
Super Hvy How Battalions								
Coastal Artillery Battalions								
Railroad Artillery Batteries								
Anti-Air Battalions							280	1
Light Anti-Air Battalions								
SP Light AA Companies							3./52*, 4./55, 4./59	3
Nebelwerfer Regiment HQs					3	1		
Nebelwerfer Regiments								
Nebelwerfer Battalions					2, 9	2		
Entgiftungs Battalions					101	1		
Machine Gun Battalions								
Anti-Tank Battalions								
SP Anti-Tank Battalions								
SP Hvy Anti-Tank Companies								
Assault Gun Battalions			665*, 667*	2/3	659*,660*,666*	1		
Flame Tank Battalions								
Mot Eng Reg HQs (Spec P)			514	1	541	1	680	1
Mot *Pionier* Battalions					44, 505	2		
(Mixed) *Pionier* Battalions			655, 657, 662	3	656, 671	2		
Bridge Const Battalions	2./566	1/3	1./566	1/3	674	1	3./566	1/3
Assault Boat Companies								
Mot Sep Bridge Cols B	122, 123	2	30, 126	2	2, 12, 121, 652, 656, 663, 671	7	1./406, 658	2
Sep Bridge Cols, Type (A-T)			5xA	5			1xH, 1xle.Z	2
Arm Mine Clearing Battalions								
Luft Flak Corps HQs								
Luft Flak Reg HQs							151	1
Luft Mixed Flak Battalions							I./13, I./291, I./411	3
Luft Light Flak Battalions								
Construction Reg HQs	35	1	7	1	16	1	I (Fr Ob)^	1
Construction Battalions	78, 132	2	98, 108	2	25, 121	2	101, 120, 306, 510R, 677R, 680R	6
Railroad Eng Reg HQs							4	1
Railroad Pionier Bat HQs							I./4	1
Railroad Pionier Companies							4./3, 1./7, 7./3, 3./5, 7./5, 3./6,306,397	8
Railroad Switching Comp's							182, 183	2
Railroad Eng Const Comp's							114, 122	2
Railroad Eng Const Batts							15	1
Mot Police Regiment HQ								
Police Rifle Battalions								
Mot Military Police Battalions							561*^	1
Mot Traffic Control Battalions							751*^	1
Armoured Trains							26, 30	2
			* 665, 667 Assault Gun Batteries were independent Batteries.		* 659, 660 and 666 Assault Gun Batteries were independent Batteries which were attached to the 600th Assault Artillery Battalion HQ (600 Abt zbV). ^ II corps also had the 4./5 mot Balloon Battery attached.		* 3./52nd Lt AA Co was attached to 253rd Inf Div. ^ Stab Fest.Pi.Kdr. I (Fortress Eng Construction Brigade 1 HQ), Redesignated 'Oberbaustab 21' on 1st Nov 41. ** Guard (Wach) and Landesschutzen units, reporting to Korück 584. *^ Motorised units reporting to Korück 584.	

[108] For example, Volumes IIB and IIIA, chapters titled ‘The Order of Battle (OOB) of German Land Combat Units from 22nd June to 4th July 1941’ and ‘The Order of Battle (OOB) of Soviet Land Combat Units on 22nd June 1941’, respectively, contain the Deployment Matrices of German and Soviet ground forces. Similar, but separate, Deployment Matrices’ are present for the respective air-forces.

[109] Refer Volume IV. The Finnish, Slovakian, Hungarian, Rumanian and Italian forces have separate Deployment Matrices for their armed forces.

[110] Refer Volume IIIA, chapter titled - ‘The Order of Battle (OOB) of Soviet Land Combat Units on 22nd June 1941’, and Volume IIIB, chapter and section titled – ‘The Soviet Air Forces in 1941 - The Soviet Aircraft Deployment Matrix’.

[111] Refer Volume IIB, 1. 2) - ‘ The Order of Battle (OOB) of German Land Combat Units from 22nd June to 4th July’, and Volume IIB, 5. 2) - ‘The Luftwaffe in 1941 - The Order of Battle and Actual Strength of all Luftwaffe Air Combat Units in a Deployed (D) State on 21st June 1941’.

6. Tables of Organisation and Equipment (TOE)

TOE is essentially a US term, and the description 'Tables of Organisation and Equipment' best describes the concepts we need for our land and air models. The Soviet equivalent term is *Shtaty* and the German term is *Kriegstarkenachweisungen* (KStN), so we will stick with TOE!

Almost every combat unit has a TOE. It is important because it is created by the military high command in order to meet the perceived demands that they believe are most likely to be placed on their forces. As such, TOEs reflected the state of the tactical, operational, and even strategic thinking in the armed forces at the time. The TOE in the land and air models is used to establish the organisational structure and authorised equipment for that particular unit. The TOE establishes the maximum combat power that can be achieved by that combat unit, and is used to control the distribution of replacements among frontline units. Along with the unit's actual strength, and in the absence of overriding operational orders, the TOE also affects the priority allocated to a combat unit to receive replacements: in general, combat units with the lowest actual strength compared to their TOE strength will have a higher priority for replacements.

Traditionally TOE's are shown in the form of an organisation chart, or an organisation list with sub-lists for the various substructures. Chart Sov RD Apr 1941 shows a typical divisional TOE structure represented in the organisation chart format. The example used is the Soviet Rifle Division TOE (or *Shtat* no 04/400-417) issued 5th April 1941. [112] This was the standard Soviet rifle division structure at the start of Operation Barbarossa. The chart illustrates well the overall organisation of the division, its command lines and what sort of primary mission it was likely to have. However information presented in this way, or in a list format, doesn't readily allow us to compare true relative strengths. It is difficult to gain a quick and accurate picture of the personnel and equipment employed in the

division as a whole, or in its immediate sub-organisations such as its regiments and battalions. Even if the required information is presented as lists on the chart, the reader is forced into the laborious and rather error prone process of calculating the total personnel and equipment for each company, battalion, regiment and finally the complete division. In addition, TOE organisation charts invariably give little to no information on transport and support infrastructures.

For these reasons we will be representing TOE information in the FILARM and PILARM models in a more detailed table format (refer entry below). The table format used will still enable the reader to rapidly gain an overview of the combat unit's overall organisational structure.

1) TOE Representation in a Table Format

In each country's FILARM or PILARM model, the initial chapters are concerned with reviewing, analysing and defining the specific resources that were available to that country from June 1941 to January 1942. The resultant list of defined resource entities is termed 'The Personnel and Equipment Resource Database', or simply the 'Resource Database', for that country. It includes equipment such as tanks, aircraft, artillery and trucks, as well as small self-contained personnel based entities such as infantry squads, cavalry squads and combat engineer squads. The methodology used to calculate the specific combat attributes of the resource entities in the Resource Database is detailed in Volume I, Part II of this work. [113]

In the respective country's land and air models, all combat units' TOEs have been broken down into the Resource Database entities for that country. Thus each combat unit's TOE displays details on the tanks, trucks, artillery pieces and infantry squads authorised for that unit. The word authorised is stressed here, because the authorised strength (or TOE) was often very different to the unit's actual historical strength.

Continuing with our example of the Soviet April 1941 Rifle Division; table Sov Rifle Div, Summary, June 1941 shows the information represented in chart Sov RD Apr 1941, but this time in table format.

Table Sov Rifle Div 1, June 1941 is an example of a TOE table showing more detail on the unit's organisation; in this case the rifle division's associated rifle regiments and battalions.

We will now use these examples to demonstrate how to read TOE's in the FILARM and PILARM models.

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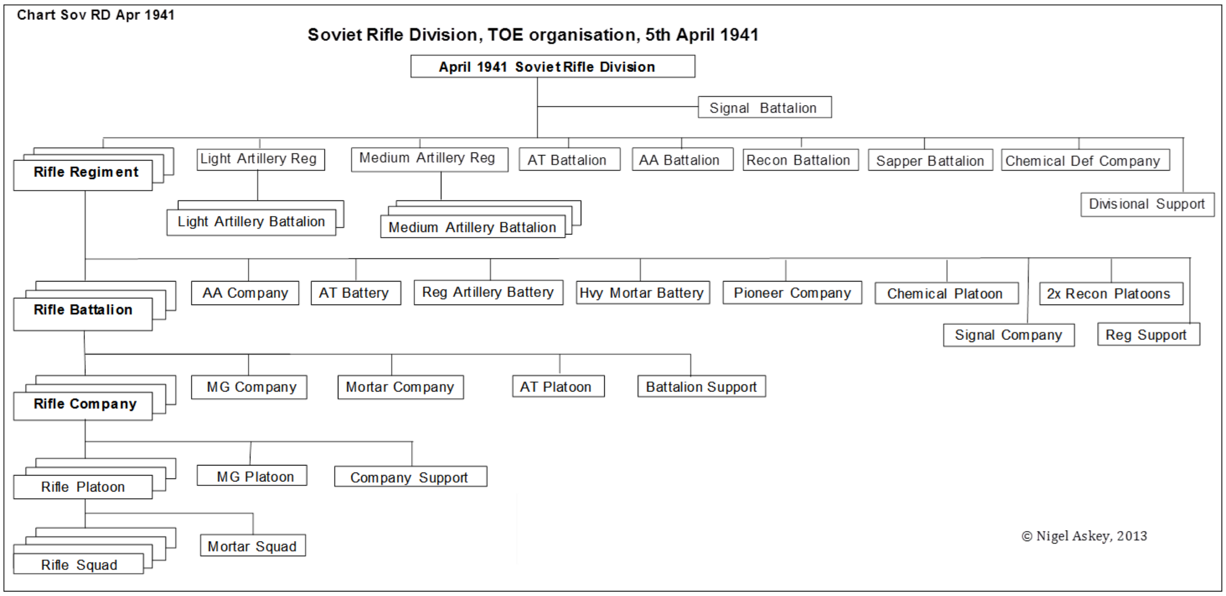

Table Sov Rifle Div, Summary, June 1941

TOE, Soviet Rifle Division, June 1941 (Combat, Signal, Transport and Supply Elements)

	RPl	**RCo**	HRC's *	B Sup ^	**R Bat**	AAC	ATC	InG Co	MoC	EnC**	ReP*^	Sig C	R Sup	**R Reg**	Lt ArR	Med ArR	Art HQ	ATB	AAB	ReB	Sig B	EnB	Chem Co	D Sup ^^	**R Div**	
Manpower	51	**178**	165	79	**778**	50	56	137	53	105	84	77	286	**3182**	1069	1250	69	221	287	282	286	571	58	844	**14483**	
	(x3)	**(x3)**			**(x3)**									**(x3)**												
Rifle Sqd	**4**	**12**			**36**						4		1	**113**						9			1		**349**	**Rifle Sqd**
L Rifle Sqd										2				**2**		12			1					6	**25**	**L Rifle Sqd**
Cav Sqd											3			**3**											**9**	**Cav Sqd**
L Cav Sqd															8		1								**9**	**L Cav Sqd**
50mm Mor	**1**	**3**			**9**									**27**						3					**84**	**50mm Mor**
LMG															12	18								4	**34**	**LMG**
MMG		**2**	12		**18**									**54**								4			**166**	**MMG**
82mm Mor			6		**6**									**18**											**54**	**82mm Mor**
Horse Team		**2**	14	24	**44**		12	42	5	7		7	106	**311**	120						14	56		22	**1145**	**Horse Team**
Trucks						9							9	**18**	16	97	7	29	34	27	19	51	18	212	**564**	**Trucks**
Light Transport													1	**1**	1	4		3	1	1	1	1		7	**22**	**Light Transport**
120mm Mor									4					**4**											**12**	**120mm Mor**
76mm Inf G								6						**6**											**18**	**76mm Inf G**
76mm Gun															16										**16**	**76mm Gun**
76mm AAG																			4						**4**	**76mm AAG**
45mm ATG			2		**2**		6							**12**				18							**54**	**45mm ATG**
37mm AAG																			8						**8**	**37mm AAG**
Tractors																75		18	5					1	**99**	**Tractors**
12.7mm AAMG						3								**3**	2	2			1					1	**15**	**12.7mm AAMG**
Quad MMG						6								**6**											**18**	**Quad MMG**
152mm How																12									**12**	**152mm How**
122mm How															8	24									**32**	**122mm How**
Light Eng Sqd										4				**4**								20	4		**36**	**Light Eng Sqd**
Ferry Br Sqd																						4			**4**	**Ferry Br Sqd**
Tankettes																				16					**16**	**Tankettes**
BA A Cars																				10	3				**13**	**BA A Cars**

* Includes Battalion Mortar Company, MG Company and Anti-Tank Platoon. ^ Includes Battalion HQ, 1x Signal Platoon, 1x Medical Section and the Battalion Trains.
** Includes the Battalion Engineer Company and Chemical Defence Platoon. *^ Includes 1x Infantry Reconnaissance Platoon and 1x Cavalry Reconnaissance Platoon.
^^ Includes 1x Truck Battalion, 1x Medical Battalion and all other Divisional Support Units. The Division was also authorised 16 motorcycles (in total).

Table Sov Rifle Div 1, June 1941

TOE, Soviet Rifle Regiment, Rifle Division, June 1941 (Combat, Signal, Transport and Supply Elements)

	R Bat (x3)	ATC*	MoC^	InG Co**	EnC*^	Chem Pl	Inf ReP	Cav ReP	AAC^^	Sig C^*	R Sup***	R Reg	
Manpower	**778**	56	53	137	85	20	52	32	50	77	286	**3182**	
Rifle Squad	**36**						4				1	**113**	**Rifle Squad**
Light Rifle Squad						2						**2**	**Light Rifle Squad**
Cavalry Squad								3				**3**	**Cavalry Squad**
Light Eng Squad					4							**4**	**Light Eng Squad**
MMG	**18**											**54**	**MMG**
AAMG									3			**3**	**AAMG**
Quad MMG									6			**6**	**Quad MMG**
50mm Mor	**9**											**27**	**50mm Mor**
82mm Mor	**6**											**18**	**82mm Mor**
120mm Mor			4									**4**	**120mm Mor**
45mm ATG	**2**	6										**12**	**45mm ATG**
76mm Inf Gun				6								**6**	**76mm Inf Gun**
Horse Team	**44**	12	5	42	3	4				7	106	**311**	**Horse Team**
Light Transport											1	**1**	**Light Transport**
Truck									9		9	**18**	**Truck**

* Includes Company HQ and 3x AT Platoons (each with a Platoon Commander and 2x AT Sections).
^ Includes Company HQ and 2x Mortar Platoons (each with a Platoon Commander and 2x Mortar Sections).
** Regimental Infantry Gun Battery. Includes Battery HQ, 1x HQ Control Platoon and 3x Artillery Platoons (each with a Platoon Commander, 1x Ammunition Supply Section, 1x Service Section and 2x Artillery Sections).
*^ Includes Company HQ and 2x Engineer Platoons (each with 4x 8-9 man Engineering Sections).
^^ Includes Company HQ, 1x AA Platoon (with 3x AAMG Sections) and 1x AA Platoon (with 6x Quad MMG Sections).
^* Includes Company HQ, 1x HQ Control Platoon, 2x Telephone Signal Platoons and 1x Radio Signal Platoon.
*** Includes HQ Staff, 1x Command Platoon (with a Security Section w. an LMG), 1x Political Section, 1x Medical Company, 1x Veterinary Hospital Platoon, 1x Supply/Services Column (with 1x Supply Company, 1x Ordnance Section and 1x Maintenance Section), and the Regimental Band.

TOE, Soviet Rifle Battalion, Rifle Regiment, Rifle Division, June 1941

	R Pl (x3)	Mg Pl	Co Sup *	R Co (x3)	MgCo ^	MoC **	ATP	Sig Pl *^	B Sup^^	R Bat	
	51	12	13	**178**	95	52	18	33	46	**778**	
Rifle Squad	**4**			**12**						**36**	**Rifle Squad**
MMG		2		**2**	12					**18**	**MMG**
50mm Mor	**1**			**3**						**9**	**50mm Mor**
82mm Mor						6				**6**	**82mm Mor**
45mm ATG							2			**2**	**45mm ATG**
Horse Team		1	1	**2**	4	6	4	3	21	**44**	**Horse Team**

* Includes Company HQ and 1x Medical section.
^ Includes Company HQ and 3x MG Platoons (each with Platoon HQ and 4x MG Sections).
** Includes Company HQ and 3x Mortar Platoons (each with a Platoon HQ Commander and 2x Mortar Sections).
*^ Includes Platoon HQ, 1x Radio Section (w 5 radios), 2x Telephone Sections and 1x Telephone Exchange Section.
^^ Includes Battalion HQ, 1x Medical Section and the Battalion Trains.

Principal References,

Soviet Rifle Regiment, June 1941 (*Shtat* 04/401 dated 5th April 1941).
S. J. Zaloga, L.S. Ness, Red Army Handbook 1939-1945, Sutton Publishing Ltd, Stroud, 1998, Table 1.2, p. 8.
C. C. Sharp, "Red Legions", Soviet Rifle Divisions Formed Before June 1941: Soviet Order of Battle WWII, Volume VIII, George F. Nafziger, West Chester, OH, 1996, pp. 104-105.
www.niehorster.org and www.rkka.ru/iorg.htm (RKKA - *Raboche Krest'yanskaya Krasnaya Armiya*).

The columns in the TOE table represent the principal divisional substructures.

A list of the most common abbreviations and nomenclature used in the columns of the TOE tables, to describe the **principal substructures,** is shown below.

TOE	Tables of Organisation and Equipment

Squads	
Sqd	Squad
R Sqd	Rifle Squad
LR Sqd	Light Rifle Squad
HR Sqd	Heavy Rifle Squad

Infantry Units	
IPl	Infantry Platoon
ICo	Infantry Company
MgPl	Machine Gun Platoon
MgCo	Machine Gun Company
HIC	Heavy Infantry Company
MG/Art Bat	Machine Gun and Artillery Battalion
I Bat	Infantry Battalion
I Reg	Infantry Regiment
I Div	Infantry Division

Rifle Units	
RPl	Rifle Platoon
RCo	Rifle Company
SMGC	Sub Machine Gun Company
HRC	Heavy Rifle Companies (HMG/Mortars)
R Bat	Rifle Battalion
R Reg	Rifle Regiment
R Div	Rifle Division

Reconnaissance and Mobile Inf Units	
ReP	Reconnaissance Platoon
ReC	Reconnaissance Company
ReB	Reconnaissance Battalion
SchBat	Schnell Battalion
BicBat	Bicycle Battalion
MoCyPl	Motor Cycle Platoon
MoCyCo	Motor Cycle Company
MoCyBat	Motor Cycle Battalion

Cavalry Units	
Cav	Cavalry
CavP	Cavalry Platoon
MGS	Machine Gun Squadron
MGT	Machine Gun Troop
SapS	Sapper Squadron
CavS	Cavalry Squadron
HCavS	Heavy Cavalry Squadron
CavT	Cavalry Troop
CavSC	Cavalry Support Company
Cav B	Cavalry Battalion
Cav Reg	Cavalry Regiment
Cav Brig	Cavalry Brigade

Weapon Types	
SMG	Sub Machine Gun
LMG	Light Machine Gun
MMG	Medium Machine Gun
HMG	Heavy Machine Gun
Mor	Mortar
ATG	Anti-Tank Gun
AAG	Anti-Aircraft Gun
Gun/Can	Gun/Cannon
How	Howitzer

Artillery and Rocket Artillery Units	
ArP	Artillery Platoon (or Battery)
ArB	Artillery Battalion
ArR	Artillery Regiment
LAR	Light Artillery Regiment
MAR	Medium Artillery Regiment
HAR	Heavy Artillery Regiment
InG P	Infantry Gun Platoon/Battery
InG Co	Infantry Gun Company
RArP	Rocket Artillery Platoon (or Battery)
RArB	Rocket Artillery Battalion
NerW Bat	Nerbelwerfer Battalion

Mortar Units	
MoP	Mortar Platoon (or Battery)
MoC	Mortar Company
MoB	Mortar Battalion

Anti Tank Units	
ATP	Anti-Tank Platoon (or Battery)
ATC	Anti-Tank Company
ATB	Anti-Tank Battalion

Anti Aircraft Units	
AAP	Anti-Aircraft Platoon
AAC	Anti-Aircraft Company
AAB	Anti-Aircraft Battalion

AFVs	
A Cars	Armoured Cars
AcCo	Armoured Car Company
TankP	Tank Platoon (or Pz P)
TankS	Tank Squadron
TankC	Tank Company (Pz Co)
TankB	Tank Battalion (or Pz Bat)
TankR	Tank Regiment (or Pz Reg)
StuGP	StuG Platoon
StuGC	StuG Company

Engineer, Sapper, Pionier, Bridging Units	
Eng	Engineering
PiC	Pionier Company
SaP	Sapper/Pioneer Platoon
SaC	Sapper Company
SaB	Sapper/Pioneer Battalion
EnP	Engineering Platoon
EnC	Engineering Company
EnB	Engineering Battalion
EnR	Engineering Regiment
Cons Bat	Construction Battalion
Br	Bridging
BrP	Bridging Platoon (pontoon)
BrC	Bridging Company (pontoon) or Bridging Column (pontoon)
BrB	Bridging Battalion (pontoon)
BrCB	Bridge Construction Battalion

Signal Units	
ASig Pl	Armoured Signal Platoon
Sig Pl	Signal Platoon
Sig C	Signal Company
Sig B	Signal Battalion

Support Infrastructures	
Tra	Transport Infrastructure
B Sup	Battalion Support
R Sup	Regimental Support
Bri Sup	Brigade Support
D Sup	Divisional Support

German Irregular Units	
LS	Landesschutzen, (Local Def Unit)
LS Reg	Landesschutzen Regiment
W	Wach
W Bat	Wach Battalion

Military Police, Security Units	
MP	Military Police
MPBat	Military Police Battalion

In some cases a column contains the total personnel and equipment for several smaller substructures which don't justify a separate column. To save space, all components of the basic common company are not shown separately. In our example (above) the rifle company (RCo) TOE includes three rifle platoons (RPIs) and a machine gun platoon. The machine gun platoon only had two MMGs and a wagon. Therefore the rifle platoons are shown separately, while the rifle company column contains all the resources in the three rifle platoons and the machine gun platoon. In other cases notes at the bottom of the table indicate were a column represents several smaller substructures.

***

The rows in the TOE table represent the defined resource entities (hence termed resources) from the relevant country's Resource Database.

In cases where no resource in the database exactly fits the piece of equipment or squad in the TOE, the closest resource in terms of size and

function is used.

Generally, the rows near the top of the table contain the most common resource types, or/and the resources found in multiple divisional substructures. In our example the rifle squad and other equipment in the rifle company is at the top of the list, because these will be repeated in several divisional substructures up to the division total. In some cases database resources are grouped together to enable easier analysis. For example, different types of MG or artillery may be grouped together, to enable an easier comparison of total MGs or total artillery pieces between various combat units.

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The TOE tables are always read from left to right, with the most common substructures on the left.

For this reason the TOE tables start with the most common substructure larger than an infantry squad in the left most column. [114] In rifle or infantry units this is usually the rifle platoon (RPl). Continuing with our example; in the rifle platoon column is the multiple (x3) and an arrow pointing to the next most common substructure, which is the rifle company (RCo). This indicates that there are three rifle platoons in the rifle company. The (RCo) column then indicates the total number of rifle squads and other equipment in the rifle company.

The rifle platoon and rifle company are identified in bold, and often highlighted in a light grey box, to indicate that they are common divisional substructures. 'Common' in this sense means that multiples of this substructure will be found in the next most common substructure. For example, multiples of the rifle company are found in the next most common substructure, which in this case is the rifle battalion (R Bat). The multiple (x3) in the rifle company column, and the arrow from (RCo) to (R Bat), indicates that there are three rifle companies in the rifle battalion. The rifle battalion (R Bat) column then indicates the total number of rifle squads and other equipment in the rifle battalion, and is identified as a another common divisional substructure. This process is repeated until the total personnel

and equipment for the division is shown in the rifle division (R Div) column.

Between the most common substructures, which in this case are the rifle platoon, rifle company, rifle battalion and rifle regiment, are other divisional substructures. These are the support platoons, companies, battalions and regiments, attached to the division and its various substructures. ‘Support’ means that, in most cases, only one of these substructures is found in the next common substructure. In our example only one anti-aircraft company (AAC) is found in each rifle regiment (R Reg), and only one light artillery regiment (LAR) is found in each rifle division (R Div). Notes on the table indicate if more than one support substructures is included in the next most common substructure. The term ‘support’ is appropriate here because in general the support substructures (or units) where designed to support other combat units in combat, even though these support units were usually capable of direct independent action if required.

In order to assist in the rapid identification of the common divisional substructures (or organisations) within the TOE tables, the following colour code is usually used in the appropriate column:

- Platoon sized organisations – blank box (no fill) or light grey.
- Company sized organisations – light brown box.
- Battalion sized organisations – light yellow box.
- Regimental sized organisations – light green box.
- Divisional or larger sized organisations – light blue or dark grey box.
- Support organisations – no colour or enclosed box.

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The TOE tables include all combat, signal, transport and supply elements.

These are included because the vital signal, transport and supply elements within combat units are often neglected and underestimated in many military simulations (and publications). In particular, the subject of battlefield logistics is cursorily treated in the majority of WWII history books. Similarly, the effects of inadequate signal infrastructure upon command and control within large combat units (brigades and larger units), and their ability to coordinate activities with other units, are often not well understood.

In many current military simulations, the impact of inadequate signal and supply elements on the combat power of combat units is often supposedly represented by abstract rules. These 'rules' may include limited cooperation between combat units, lengthy artillery set up times, and temporary loss of control. However these abstractions tend to underestimate the impact of poor signal, transport and supply elements on overall combat power. By including the main equipment of these elements in the TOE tables (usually in the form of personnel and vehicles), it becomes much clearer where the strengths and weaknesses of specific types of combat units lay.

For example, we can see from our example that the Soviet April 1941 rifle division had two artillery regiments capable of indirect artillery fire. The light and medium artillery regiments (LAR and MAR) had 60 76-152mm calibre artillery pieces between them; a formidable number. In comparison a German first wave infantry division had a single artillery regiment with 48 105-150mm calibre artillery pieces. Therefore, based on weapon numbers alone, the April 1941 rifle division appears to have more indirect artillery fire capability than a German first wave infantry division. However the Soviet division's signal battalion had only 19 trucks and light transports to service the division, while the German division's signal battalion had 96: over five times as large. Indirect artillery fire requires a lot of artillery support parameters to be in place, particularly a large and sophisticated signals system. [115] When one considers that the Red Army also suffered from a chronic shortage of radios in almost all their combat units (even compared to the relatively few radios authorised in the TOE), and equipment and training shortages in other areas, it becomes apparent that most Soviet rifle divisions in 1941-42 where not capable of indirect fire

operations in a mobile battle. This is confirmed by German combat reports which mention the ineffectiveness of Soviet artillery support during 1941. In effect, most Red Army artillery units in 1941 could only fire effectively at what their gun crews could see.

Frustratingly, some current military simulations assume that giving the Soviet 1941 artillery a longer set up time after movement compensates for all the above problems. Once set up, the Soviet artillery is assumed to have had the same indirect fire capability as the average Wehrmacht division, or even a modern day division. In actuality, regardless of how long the artillery units took to set up, the sophisticated signal network required to enable flexible indirect artillery fire missions simply didn't exist in most rifle divisions in 1941. In addition, indirect artillery fire cooperation with units in the same corps, let alone units in other corps or armies, was almost impossible. The average Soviet 1941 rifle division had major problems providing any effective indirect artillery fire support, even to its own subunits in a relatively static defensive situation.

The often severe impact of inadequate signal, transport and supply elements on the combat power of combat units is demonstrated in various sections and chapters of this book, and is why these elements are shown in all TOEs if possible.

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In summary, the advantages of the TOE table format include the following.

- The table format still enables the overall organisation of the combat unit and its command lines to be easily understood.
- The reader is able to establish individual company, battalion, regimental and divisional strengths at a glance without any calculations. This enables true relative strengths to be easily compared for similar sized combat units.
- Information on signal, transport, supply and support infrastructures are represented and more easily shown. This also enables truer relative

strengths to be easily compared when assessing the overall potential combat power of a combat unit.

- Small and large TOE variations between divisions of the same type can be easily identified. Sometimes divisions of the same type appear to have almost identical TOEs. On an organisation chart (or list) the small and subtle differences can be difficult to spot, and are sometimes underestimated or ignored completely. With the table format these differences are immediately apparent. For example, the subtle differences between German first wave and second wave infantry divisions in the German land model are very apparent in the table format, but appear insignificant and hard to identify in the more traditional organisation chart format. [116]

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[112] Sharp, C, C, 'Red Legions': Soviet Rifle Divisions Formed Before June 1941, Soviet Order of Battle WWII: Volume VIII, George F. Nafziger, West Chester, OH, 1996, pp. 104 and 105. Also, Zaloga, S, J, Ness, L, S, Red Army Handbook 1939-1945, Sutton Publishing, Stroud, UK, 1998, pp. 5-10, tables 1.2 and 1.3.

[113] Refer Volume I Part II – 'The Methodology Used for Analysing Weapon System Effectiveness, and the Structure of the 1941 Soviet and Axis Resource Database'.

[114] The squad or half squad was usually the smallest tactical unit identified by command and control systems, and which operated as a complete combat entity in WWII. This has not changed much since WWII. Normally, only 'special forces' operated smaller combat units than this. Note, some armies and sources refer to a squad as a 'section', or a full squad as a 'squad' and a half-squad as a 'section'.

[115] Refer to Volume V – 'Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces from 1941-1945' for discussion on artillery support parameters required to enable indirect artillery fire, as well as the relative ability of the Red Army and Wehrmacht to conduct indirect artillery fire operations in 1941.

[116] Refer Volume IIA 3. 2) – ' The Tables of Organisation and Equipment (TOE) for German Land Combat Units from 22nd June to 31st December 1941, and the Unit's Actual Organisation and Equipment in 1941 - German Army Infantry Units'.

7. The Heterogeneous vs. the Homogeneous Model

It is important to understand that <u>the TOE was not the actual equipment or personnel that existed in most combat units</u> . It was relatively rare for combat units to achieve their TOE during WWII. This was especially true after the start of hostilities, and particularly true for German and Soviet units on the East Front. It would be true to say that the average Soviet or German division never reached their TOE strength at any stage on the East Front after June 1941. By the end of the war many German divisions on all fronts were down to battalion strength or even less, and despite the common perception of the Red Army as a juggernaut in 1945, the average Soviet rifle division wasn't much better off. For example, during Operation Bagration in 1944 the average Soviet rifle division had a strength of around 6 000 men. No serious effort was made to bring them up to their TOE strength of around 9 600 men, despite Bagration being a massive offensive with concentrated and replenished forces. [117]

The US Army's units were most likely to be at or even over TOE strength, followed by the British Army, during WWII. Both these armies fielded far fewer divisions than the Red Army or the German Army, although their 'divisional slices' were often over five times as large (i.e. the average actual division size, and adding corps and army support units and infrastructure) [118] In addition, the average US and British division saw less continuous action because they were usually pulled out of the line to refurbish and receive replacements once the division's combat elements hit around 70-80% of TOE, and on average they received a much higher number of personnel and equipment replacements. US war-production levels and a comparatively plentiful supply of manpower even enabled some US divisions to 'hoard' equipment prior to a major campaign. In these cases they occasionally exceeded their TOE by a significant margin, especially in the transport area. All these factors are some of the main

reasons why it is very misleading to use numbers of divisions on a particular front to compare opposing force strengths. [119]

Many military simulations make the serious mistake of using a combat unit's TOE as its actual start strength in a campaign or battle. Could this be because the majority of them are written by US or other Commonwealth countries? If the simulation at least attempts to replicate the difference between TOE and actual strength, it is often underestimated just how far below their TOE strength many units actually were. Upon further analysis it is not difficult to see why it is easy to take the TOE strength (which is easily available), multiply by a figure of 70-100%, and then claim historical accuracy. The main problem is historical research and the difficulty in finding out what any particular combat unit actually had at the time in question. In some cases excellent records exist detailing the division's actual personnel and equipment strengths. In the majority of cases however these records don't exist, or are not available for a specific time and place.

Nevertheless, extensive records do exist, and often the information they present can be pieced together like a giant jigsaw puzzle in order to build a reasonably accurate picture of the actual personnel and equipment in the combat units concerned. Very often this information is indirect, or relevant information is available about a higher level unit up the command chain. For example, the total personnel and equipment in a division may not be available at a given time, but information relating to the corps it was assigned to may be well documented.

One of the principal aims of the Fully Integrated Land and Air Resource Model (FILARM), is to provide a framework and methodology to assist and enable the 'actual personnel and equipment jigsaw' to be put together. The aim is to establish an accurate measurement of the actual personnel and equipment available for the combat units concerned at the start of the campaign, and for the duration of the campaign. This leads us to the terms **heterogeneous (or non-homogeneous) model**, **homogeneous model**, and **checksums**, used in our land and air models.

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1) The Heterogeneous Model

In the heterogeneous model, reasonably detailed and reputable historical records exist of individual combat unit's (usually divisions) actual strength at the relevant place and time. In this case the actual personnel and equipment is used in the model as well as the combat unit's TOE. As each combat unit has a unique list of personnel and equipment, each combat unit is modelled separately and is different to all other units. Hence the term heterogeneous: composed of unlike parts. If the replacement and reinforcement figures for personnel and equipment are also available, then the heterogeneous model represents the most accurate model available in terms of measuring the true historical strength.

However sufficient information to build a purely heterogeneous model is rare. Usually partial information on combat units, or complete information on only selected units, is available. As a result most land and air models are a composite of heterogeneous and homogeneous models.

2) The Homogeneous Model and the use of Checksums

In the homogeneous model, reputable and sometimes detailed historical records exist of total personnel and equipment in larger formations (usually larger than divisions), but not for all the individual combat units in the formation. The formations concerned are usually corps, armies, fronts, army groups or even the theatre of war. Accurate information on some of the combat units may be available, and additional information may be available such as average divisional strengths within a given formation.

In this case the actual personnel and equipment is calculated based on the Order of Battle (OOB) of the formation being considered, taking into account any available information on individual combat units in the formation. [120] The calculation 'checksum' is that the total personnel and equipment in the formation (from historical record), must equal the total personnel and equipment in all the combat units in the formation's OOB. The checksum can be described by the following equation.

$$\sum_{1}^{x_{Total}} Formation = \sum_{1}^{x_1} Combat\ Unit_1 + \sum_{1}^{x_2} Combat\ Unit_2 + \sum_{1}^{x_3} Combat\ Unit_3 \ldots\ldots$$

Where: x is the personnel and equipment, *Formation* is the corps, army, front, army group or theatre of war being considered, and *Combat Unit* is the individual division or smaller unit within the Formation's OOB.

If no specific information about the individual combat units within the formation is available, then obviously the personnel and equipment is distributed evenly across the units in the formation's OOB. Hence the term homogeneous: composed of like parts or undifferentiated. Most often partial information on at least some of the combat units is available. In this case the individual unit's information is used, but the personnel and equipment in the remaining units in the formation's OOB still has to ensure the checksum equation remains valid. Hence most land and air models become a composite of heterogeneous and homogeneous models.

It is important to understand that the checksum principle remains valid as one proceeds up the chain of command. A higher formation such as a Soviet front or military district may have several armies, each with several rifle corps, and each in turn with several divisions. Hence the total personnel and equipment in the front must equal the total in all the armies in the front's OOB. In turn the total personnel and equipment in each army must equal the total in all the rifle corps in the Army's OOB, etc. Obviously any separate or independent units reporting directly to a HQ, such as supply units or RVGK artillery units, must be included in the checksum for that HQ. [121] The checksum methodology is essentially an application of the principle underlying the Fully Integrated Land and Air Resource Model (FILARM); namely the conservation of resources, where the resources represent all mobilised personnel and all types of equipment.

The best way to illustrate the checksum methodology 'in action' is by taking a specific example. On 22nd June 1941 the Soviet 4th and 7th Tank Divisions, and the 29th Mechanised Division were part or the 6th Mechanised Corps. The 6th Mechanised was in turn attached to10th Army

which was part of the Western Special Military District. The latter HQ became the Western Front on 22nd June after Operation Barbarossa started.

One source indicates that on 22nd June the individual divisions had the following tanks: [122]

- 4th Tank - 63 KV, 88 T-34, and over 200 BT-5, BT-7, T-26, and possibly others.
- 7th Tank - 51 KV, 150 T-34, 125 BT-5/BT-7, and 42 T-26.
- 29th Mechanised – 275 tanks (mostly BT-5, BT-7, T-26) and tankettes, with approximately 1/3 of the total being T37/38 tankettes.

  Another source indicates that on 22nd June the individual divisions had the following tanks: [123]

- 4th Tank - 63 KV, 160 T-34, 93 BT, 72 T-26s (incl flame types) and 64 tankettes.
- 7th Tank - 51 KV, 78 T-34, 134 BT, 54 T-26 (incl flame types) and 46 tankettes.
- 29th Mechanised - 183 BT and 17 and tankettes.
- 6th Mechanised Corps HQ - 6 BT (radio tanks).

All sources agree that the 6th Mechanised Corps had 238 T34s and 114 KV tanks at the start of Operation Barbarossa. [124] This is verified by most other accounts which also state 6th Mechanised Corps had 352 new model tanks, out of a total of 1 021 tanks and tankettes. [125] Another source indicates there were 1 131 tanks and tankettes in 6th Mechanised Corps, but does not indicate how many were new T-34 or KV tanks. [126] Given the weight of evidence, it appears much more likely that the figure of 1 021 tanks and tankettes in 6th Mechanised Corps on 22nd June 1941 is the most accurate.

This enables us to do our first checksums. For example, the number of T-34 and KV tanks in the 4th and 7th Tank Divisions is the same as the

number in 6th Mechanised Corps. In addition the total number of new tanks (352) is consistent between sources, and if the 6th Mechanised Corps had 1 021 tanks and tankettes then the total number of tanks in 4th, 7th and 29th Divisions, and the corps HQ, must equal this number.

In addition the number of tanks and tankettes in the whole Western Special Military District on 1st June 1941 is known to be 1 389 T-26s, 462 T-37/38/40/50 tankettes, 63 T-28s, 251 BT-2/5s, 410 BT-7/7Ms, 228 T-34s, 75 KV-1s and 22 KV-2s. [127] An additional 38 T-34s and 20 KVs arrived in the Special Western Military District between 2nd and 22nd June 1941. Therefore the total number of 266 T-34 and 117 KV tanks were present in the Special Western Military District (Western Front) on 22nd June 1941. In addition we have a great deal of information about the tanks in the other mechanised corps (and other non-armoured and none-mechanised divisions) in the Western Special Military District. This includes information such as that the 11th Mechanised Corps had 28 T-34s and 3 KV tanks (with 26 T-34s and 2 KVs in the 29th Tank Division and 2 T-34s and 1 KV in the 33rd Tank Division), and that no other combat units in Western Front had T-34s or KVs. All this information is presented in the Soviet Tank Deployment Matrix. [128]

These figures then enable a second series of checksums to be made higher up the chain of command. For example, we can see that the 4th, 7th, 29th and 33rd Tank Divisions in Western Front most likely had 88, 150, 26 and 2 T-34s, and 63, 51, 2 and 1 KV tanks, respectively. This equals the Western Front's total figure of 266 T-34 and 117 KV tanks (including the 38 T-34s and 20 KVs which arrived in the Special Western Military District between 2nd and 22nd June 1941). Similar analyses can be carried out for other tank types, with the detailed results shown in the Soviet FILARM model and the Soviet Tank Deployment Matrix. [129] In our example above we find that, with all the checksums at all levels complete, the most likely tanks in 6th Mechanised Corps on 22nd June 1941 were as follows:

- 4th Tank - 43 KV-1, 20 KV-2, 88 T-34, 93 BT, 72 T-26s (incl flame types) and 64 tankettes (total 380 tanks)

- 7th Tank - 40 KV-1, 11 KV-2, 150 T-34, 134 BT, 54 T-26 (incl flame types) and 46 tankettes (total 435 tanks)
- 29th Mechanised – 183 BT and 17 and tankettes (total 200 tanks)
- 6th Mechanised Corps HQ - 6 BT (radio tanks).

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It should be noted that in many cases conflicting information will occur. In this case the 'investigator' has to first evaluate the source. Questions need to be asked such as: why may it be inaccurate? Was it a quick combat report made on the run? Does it include vehicles not normally classified as tanks? Did new equipment arrive and was equipment in transit included? The researcher will have to make a judgement call in many cases while attempting to cross reference multiple sources if possible.

Despite the conflicting information however, it has been surprising how successful the checksum methodology is in obtaining accurate figures on actual personnel and equipment. Very often the size of the discrepancies is small. This can usually be attributed to the continuous movement of inventory in and out of combat units and rear area workshops, units being transferred between HQs, and units simply being in transit.

In addition, the researcher working on achieving a realistic military simulation has the benefit of knowing that the overall combat power of the formation being analysed will be very close to the real value. This is the case even if a significant error has been made in determining the distribution of combat power within the combat units of the formation. Using our example above; even if the tanks in 4th Tank Division have been underestimated, the consequential increase in tank numbers in the other divisions in 6th Mechanised Corps will ensure the overall combat power of 6th Mechanised Corps is maintained at a realistic level. This applies to formations all the way up the chain of command, and to the Soviet Western Front as a whole.

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[117] S. Zaloga, Bagration 1944, Osprey Military Campaign Series, Reed International Books Ltd, London, 1996, pp. 27 and 28. By 1945 the average rifle division was considerably smaller than even this.

[118] 'Division slice' is military jargon to indicate a force's true strength. It is essentially calculated as the total force strength in the field divided by the number of divisions. Refer Volume I Part I 9. 1) – 'What was a Divisional Sized Combat Unit in 1941?' for more on this.

[119] Ibid.

[120] Order of Battle or OOB is a common military term describing a list of combat units in a given formation at a given time.

[121] RVGK (Reserve of the high command) artillery, attached to army or front HQs.

[122] C. C. Sharp, "The Deadly Beginning", Soviet Tank, Mechanised, Motorised Divisions and Tank Brigades of 1940-1942, Soviet OOB of WWII: Volume I, George F. Nafziger, West Chester, OH, 1995, pp. 20, 22 and 54. 7th Tank Division figures are for 1st June 1941.

[123] A. Smirnov, A. Surkov, 1941: *Boi v Belorussii, Frontovaya Illyustratia* (Frontline Illustration), Moscow, 2003.

[124] S. J. Zaloga, P. Sarson, T34/76 Medium Tank 1941-1945, Osprey Military, London, 1994, p. 11. Also S. J. Zaloga, J. Kinnear, P. Sarson, KV1 and 2 Heavy Tanks 1941-1945, Osprey Military, London, 1995, p. 16. Also, A. Smirnov, A. Surkov, 1941: *Boi v Belorussii, Frontovaya Illyustratia* (Frontline Illustration), Moscow, 2003. Also, C. C. Sharp, "The Deadly Beginning", Soviet Tank, Mechanised, Motorised Divisions and Tank Brigades of 1940-1942, Soviet OOB of WWII: Volume I, George F. Nafziger, West Chester, OH, 1995, pp. 20 and 22.

[125] The Initial Period of War on the Eastern Front, 22nd June-March 1941: Proceedings of the 4th Art of War Symposium, Garmisch Oct 1987, ed. D.M. Glantz, Frank Cass, 1993, pp. 36, figure 32. Also, Colonel D, M. Glantz, research paper "Red Army Ground Forces in June 1941", Glantz, 1997, p. 43, Table 10. This figure is also verified by C. C. Sharp, "The Deadly Beginning", Soviet Tank , Mechanised, Motorised Divisions and Tank Brigades of 1940-1942, Soviet OOB of WWII: Volume I, George F. Nafziger, West Chester, OH, 1995, and also by, A. Smirnov, A. Surkov, 1941: *Boi v Belorussii, Frontovaya Illyustratia* (Frontline Illustration), Moscow, 2003.

[126] D. M. Glantz, Stumbling Colossus, University Press of Kansas, Lawrence, Kansas, 1998, p. 155, table 5.5. This source also details the number of men, armoured cars, artillery, mortars, vehicles, tractors and motorcycles that were present in the Soviet Mechanised Corps in the Western Military Districts on 22nd June 1941.

[127] C. Crofoot , The Order Of Battle Of the Soviet Armed Forces: The Sleeping Bear, Volume 1: 22nd June 1941, Part One, The Nafziger Collection Inc, West Chester, OH, 2001, pp. 21 and 22. Also verified by A. Smirnov, A. Surkov, 1941: *Boi v Belorussii, Frontovaya Illyustratia* (Frontline Illustration), Moscow, 2003.

[128] Refer Volume III, chapter and section titled - 'The Actual Strength of all Soviet Land Combat Units in a Deployed (D) State on 22nd June 1941 - The Soviet Tank Deployment Matrix' for full details of all Soviet tanks deployed on 22nd June 1941.

[129] Ibid.

8. Supply Distribution Efficiency (SDE)

In the FILARM model, the relative Supply Distribution Efficiency (SDE) is a measure of the ability of support infrastructures to supply and support combat units (of a specific number and type), over a fixed distance and terrain, during combat operations.

The support infrastructures include divisional and smaller unit internal support organisations, as well as all corps, army and front level support units. Although not stated in the title, SDE includes the ability of these same support infrastructures to maintain equipment in an operational condition. This includes maintenance, repair and recovery of equipment.

There is a famous saying in the military, "amateurs study tactics, professionals study logistics". Although the quote somewhat overstates the importance of logistics (professionals should study tactics and logistics), it does drive home the importance of SDE in any military operation. SDE affects combat units directly at the tactical and operational level, and it affects combat units in the short and long term. Most combat units will run low on ammunition within a day of continuous combat if not resupplied, especially in mobile operations. The Relative Overall Combat Proficiency (ROCP) of any armed force is a measure of combat proficiency across both tactical and operational levels. Hence the SDE of any given army and air force is an integral part of its Relative Overall Combat Proficiency (ROCP). [130]

In researching for this work the question arose: what universal parameter best measured the support infrastructure for the multitude of different combat unit types involved? The most significant parameter that directly reflected SDE in all combat unit types is the amount of available transport. Obviously the ability of dedicated supply units to do their job was proportional to the amount of transport available. However support units which had functions such as HQs, repair, recovery, maintenance, radio signals, landline signals, ambulance columns, field hospitals, veterinary,

field kitchens, bakery, quartermaster and military police, all gained direct benefit from having more transport; preferably motorised. In almost all cases, conventional infrastructure capability was directly proportional to the amount of transport available. More specifically, the support unit's capability was directly proportional to the amount of 'supply lift' available, where supply lift is measured in metric ton kilometres per day (the product of the mass that can be moved and the distance it can be moved in one day).

Obviously the capability of support units such as field hospitals and signals is greatly influenced by the amount of non-transport related equipment and personnel available. But, invariably, the more non-transport related resources they were authorised, the more transport they were authorised to move and support their equipment and personnel. In many cases the only available transport was horse drawn. This is the main reason why TOEs should include all transport in combat, signal, transport and supply elements. The authorised TOE and its comparison to actual available transport, then enables an evaluation to be made of the effect of SDE on the true combat power of the unit.

The importance of SDE is demonstrated in diagram FILARM showing the general structure of the Fully Integrated Land and Air Resource Model (FILARM). One of the seven resource allocation states is 'Supply and Support Infrastructure'. 'Supply and Support Infrastructure' receives resource allocations from all the 'campaign reserve states' and sends resource allocations to all combat units, regardless of their deployment state. What this means in practical terms is that if more of the total available transport is allocated to combat units, then they will have higher mobility and lower SDE. If support infrastructure receives more of the available transport, the average combat unit mobility will be lowered but the overall SDE will increase (i.e. an integrated system). It should be noted here that the SDE calculation involves combat unit (e.g. divisional) internal support infrastructure, as well as corps and army level support infrastructure. Therefore transport allocated to combat units will still benefit that side's SDE, but to a lesser degree (refer to SDE equations below).

In the FILARM and PILARM models, the value of a force's SDE is given by the following equation.

$$SDE_{Force}(\%) = \frac{Supply\ Lift_{All\ Support\ Infrastructure}}{Supply\ Demand_{All\ Combat\ Units} * Supply\ Radius_{km}} * C_{Weather} * \frac{1}{10}$$

Where: $Supply\ Lift_{All\ Support\ Infrastructure}$ is the product of the supply mass that can be moved, and the distance it can be moved per day (measured in metric ton kilometres per day) by all support infrastructures. These include divisional and smaller unit internal support organisations, as well as all corps, army and front level support units.

$Supply\ Demand_{All\ Combat\ Units}$ is the supply demand per day of all combat units supported by the above infrastructures, during combat operations (measured in metric tons per day).

$Supply\ Radius_{km}$ is the fixed distance (measured in kilometres) over which the SDE is being measured. In the FILARM and PILARM models this is 100kms.

$C_{Weather}$ is a modifier for the weather during the period the SDE is being considered. In most cases this equation constant is the same for opposing forces so weather effects usually cancel out when considering relative SDE values. In certain circumstances however, one side may have a higher 'weather constant' value due to special conditions. An example of this in Operation Barbarossa was the winter conditions in November/December 1941, when the Soviets were more prepared for supplying units in freezing or blizzard conditions.

The 1/10 is a scaling factor (so the SDE is in the form of a meaningful percentage).

The one major parameter not explicitly considered in the SDE equation above is the terrain over which the SDE is being measured. Obviously supply over mountainous, swampy or jungle terrain is much more difficult than along tarmac roads. The terrain factor is built into the $Supply\ Lift_{All\ Support\ Infrastructure}$ value, because here we consider the ability of different supply-transport vehicles to move over the terrain being considered. For example, in extremely mountainous terrain the ability of trucks to move

drops almost to zero, while horses (particularly pack horses) can still move 10-25 km per day (refer below on how Supply Lift is calculated).

It is important to note that SDE drops rapidly as the distance over which supply and support is to be provided increases. In the respective Soviet and German FILARM models we will see that during Operation Barbarossa the Germans enjoyed a considerably higher level of SDE than the Soviets. However, during 1941 the German supply systems usually had to operate over much longer distances than their Soviet counterparts. If their railhead supply depots failed to keep up with the front, or the supply distance was dramatically increased due to interdiction type attacks on bridges, etc, the German SDE rapidly approached that of the Soviets. Note however that this was a two edged sword. Because the Germans gained air superiority, the Luftwaffe was more capable of severely damaging rail networks, bridges and local supply depots; forcing the Soviet truck and horse drawn supply systems to operate over longer distances. [131]

1) Supply Lift

In the FILARM and PILARM models the available Supply Lift (measured in metric ton kilometres per day) of a force's support infrastructure is given by the following equation.

$$\begin{aligned} \textit{Supply Lift}_{\textit{All Support Infrastructure}} &= (T_{RA} * L_T * D_T) + (LT_{RA} * L_{LT} * D_{LT}) + (TR_{RA} * L_{TR} * D_{TR}) + \\ & 0.3 * ((T_{TOE} * L_T * D_T) + (LT_{TOE} * L_{LT} * D_{LT}) + (TR_{TOE} * L_{TR} * D_{TR})) + 0.5 * (H_{TOE} * L_H * D_H) \end{aligned}$$

Where: The suffix RA is 'Rear Area'. Rear area in this case means not assigned to the TOE for any Deployed (D), MD or MND combat unit.

The suffix TOE means 'assigned to a units TOE', that is to say included in the TOE for any Deployed (D), MD or MND combat unit.

T is the number of available Trucks. Trucks include non-tracked vehicles with a designed load capacity of one metric ton or over.

LT is the number of available Light Transports. Light Transports include non-tracked vehicles which are not trucks.

TR is the number of available Tractors or prime movers. Prime movers includes fully or
half-tracked vehicles, including artillery tractors and recovery vehicles.

H is the number of available Horse teams. Horse teams include artillery hitch and limber teams (4-8 horses each), separate horse drawn vehicles such as carts, wagons or field kitchens, and groups of six pack horses.

L is the average load capacity of the motorised vehicle or horse team, measured in metric tons. The L suffixes *T, LT, TR* and *H* denote Truck, Light Transport, Tractor and Horse Team, respectively.

D is average distance the fully loaded motorised vehicle or horse team can move in one day (measured in kilometres per day), over the terrain in which the SDE is being measured. The D suffixes *T, LT, TR* and *H* denote Truck, Light Transport, Tractor or Horse Team, respectively.

The supply lift equation means that all ‘unassigned’ transport in rear areas, as well as 30% of motorised transport and 50% of horse drawn transport in the TOE of combat units, is available for supply and support services. In addition the inclusion of all prime movers ensures support structures include maintenance, repair and recovery equipment.

2) Supply Demand

In the FILARM and PILARM models the Supply Demand (measured in metric tons per day) of all combat units during combat operations is given by the following equation.

$$Supply\ Demand_{All\ Combat\ Units} = \left(\sum_{x=1}^{x=n} WS - Sqd\ type\,1\,SDF_x\right) * 0.1 + \left(\sum_{x=1}^{x=n} WS - Sqd\ type\,2\,SDF_x\right) * 0.1$$
$$+ \left(\sum_{x=1}^{x=n} WS - Sqd\ type\,3\,SDF_x\right) * 0.1 \ldots\ldots\ldots\ldots + Ave\ No\ Listed\ Personnel / 1000$$

Where: *WS - Sqd type SDF* is the specific weapon system or squad type **Supply Demand Factor** (SDF), calculated using the methodology used for creating the FILARM database (detailed in Part II of this volume). [132] Note, the Supply Demand Factor (SDF) for individual weapon system or squad

types is expressed in units of 100kg per day: hence the 0.1 correction to express the overall Supply Demand in metric tons per day.

n is the number total number of specific weapon system or squad types in the force, e.g. the number of heavy infantry squads, or the number of T-34 tanks, or the number of 76mm howitzers, or the number of BF-109 fighters, etc.

Ave No Listed personnel is the average number of personnel in the overall forces during the period under consideration. For example, if attempting to calculate SDE over a period of months then this should be the average monthly listed strength. This component of the supply demand equation is to account for the relative food and water consumption by the overall force.

In calculating the SDF attributes for database resources (weapon systems and squads) we considered factors for ammunition and fuel consumption, as well as overall support in terms of maintenance, repair and recovery. Food and water consumption was not included in the SDF attribute. However food and water consumption needs to be considered in the overall force's SDE, and so is included here. This allows personnel in rear areas such as Air Force support personnel or rear area supply units, which may not be included in the Deployment Matrix and which do not have a combat unit TOE, to be included in the overall force's supply demand. These units consumed very little ammunition, and any fuel they used is already accounted for in the SDF value calculated for trucks and light transports.

Inclusion of food and water consumption at this point also allows adjustments to be made for any soldier's ability to 'live off the land'. In WWII Soviet soldiers reputably required less support than equivalent western soldiers. This is attributed to their cultural background, their familiarity with the harsh weather conditions in the USSR and their ability to utilise surrounding resources for food. The Soviet soldier's ability to survive on fewer supplies may have been true for food and water, but ammunition, fuel and spare parts still had to be supplied by the armed force's infrastructure and the war economy. Judging by the low SDE values calculated in the Soviet FILARM model, Red Army soldiers probably lived

off the land because they often had little choice. It is interesting to note that in general on the East Front in WWII, German Army units cut off and out of supply lasted considerably longer than Red Army pockets, even though the German pockets were usually smaller and therefore easier to liquidate. Examples of such German pockets are Demyansk, Stalingrad, and Korsun, all of which lasted weeks or months despite being under continuous assault. The much larger Soviet pockets formed in 1941/42 were eliminated in days or at most weeks. All this was probably due to several unrelated factors, but it does fly in the face of the general opinion that Soviet soldiers needed fewer supplies to function normally. Nevertheless, to take account of the Soviet soldier's apparent ability to obtain food from the surrounding countryside, the *Ave No Listed personnel* is divided by 1500 in the Soviet SDE calculation in the Soviet FILARM model. This assumes the average Soviet soldier needed 33% less supplied food and water than the average soldier in the opposing Axis forces, to function at the same level.

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[130] Refer Volume V - 'Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces from 1941-1945'.

[131] One of the most extreme cases in WWII of pure air interdiction reducing SDE to fatally low levels was during the Normandy campaign in 1944. For the Germans, not only was rail transport suicidal anywhere near Normandy (if the rail or bridges were still intact), but trucks and horses were forced to bring up most supplies at night.

[132] Refer Volume I, Part II 3. 10) - 'The Methodology Used for Analysing Weapon System Effectiveness, and the Structure of the 1941 Soviet and Axis Resource Database - Methodology for Calculating a Weapon System's or Database Unit's Specific Combat Attributes - Supply Demand Factor (SDF)'.

9. A Divisional Sized or Division Equivalent Combat Unit in WWII

In most military history studies regarding the 20th century, the terms division, ‘division equivalent’ and ‘division sized’ are used freely to describe the size of a particular designated combat unit. This is standard military history terminology and makes sense because traditionally a division represented the smallest self-sufficient combined arms formation on the battlefield. Although supported by a multitude of smaller ancillary land and air units, it was the divisions which represented the primary offensive strength of any army. As a result one would assume that counting divisions or division equivalents is a reasonably accurate way to assess an army’s strength.

Unfortunately, reality, as usual, is much more complicated than this. In fact simply counting the number of divisions in opposing forces almost always leads to very inaccurate, incorrect and just plain misleading assessments of an army’s true strength. [133] The reason is that the terms division, division equivalent and division sized, are totally ambiguous and subjective. There are several reasons for this.

Firstly, division sizes and structures varied immensely depending on their primary mission. For example, cavalry divisions tended to be much smaller and lighter (fewer heavy weapons) than rifle or infantry divisions, but they had more transport to improve mobility. Armoured divisions tended to have considerably fewer personnel than rifle or infantry divisions, but a lot more heavy weapons and equipment. The various division types may have been all called divisions, but in terms of size and overall combat power they were almost never ‘equivalent’.

Secondly, divisions of a certain type varied tremendously from one country’s army to another for many reasons, including:

- Each country’s military objectives were different.

- The state of development of the ‘art of war’ varied by country depending on history and doctrine.
- Different country’s armies had different resources available.
- Divisions were often structured to suit local terrain and conditions.

Thus various country’s infantry divisions may have all been called ‘infantry divisions’, but in terms of size and overall combat power they were also rarely ‘equivalent’.

In the FILARM and PILARM models relating to Operation Barbarossa we will be analysing the TOEs of all the land combat units involved. In addition we will be examining the actual equipment available in these units. When assessing the strength of divisions and brigades in a combatant’s armed forces we will naturally be using the terms division, division equivalent and division sized. However to avoid the ambiguity and misleading conclusions resulting from uncontrolled use of these terms, we need a yardstick or reference to decide the criterion on which a combat unit can be classified as division sized. By comparing to a ‘reference division’ (see below) we can establish if a ‘division’ was a division in name only, and if so what proportion of a division sized unit it really was.

For the purposes of the FILARM and PILARM models, this analysis will only be carried out on combat units designated by their respective country’s armed forces as ‘brigades’ or ‘divisions’. Where designated ‘divisions’ exceed the criterion set by the ‘reference division’, they will simply be designated as division sized. We are principally interested in the many smaller units involved in Operation Barbarossa which were designated as ‘divisions’ or ‘brigades’.

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1) What was a Divisional Sized Combat Unit in 1941?

Given that ‘divisions’ and ‘divisional sized’ are terms so widely used in comparing force strengths, it is not unreasonable to ask: in the context of WWII, what is a divisional sized combat unit and how should this be

assessed? As soon as one thinks about this, it becomes subjective. Should it include numbers of personnel and weapons only, or should divisional supply and support infrastructures be included? We have already seen the effect a weak Supply Distribution Efficiency (SDE) can have on a combat force's overall combat power.

By far the most common division type in WWII was the Red Army's rifle or comparable western infantry division, so it is reasonable to examine the authorised structure (TOE) of various armies' rifle-infantry divisions to gain an insight into the question above. It should be borne in mind in the following discussion that the TOE was usually different to the actual personnel and equipment in the division: very few countries had all the resources required to bring their divisions up to full strength. However full TOEs were what each country's army command strived for, and TOEs are a very strong indicator of the resources that were available to that country as well as the state of their military thinking and development.

The Soviet pre-war rifle division at full strength was a powerful force and was generally equivalent to the traditional western idea of a division. It included approximately 14 500 men, 392 LMGs, 166 MMGs, 1100 horse teams, 585 trucks, 22 light transports, 54 AT guns, 84 50mm mortars, 54 82mm mortars, 12 120mm mortars, 34 76mm artillery pieces and 44 122-152mm artillery pieces. The Soviet pre-war rifle division was particularly strong in terms of medium to heavy artillery and included a light and medium artillery regiment in its TOE. Fortunately for the invading Germans, not one rifle division in the Red Army was at full strength on 22nd June 1941.

In 1941 a first wave German line infantry division included almost 16 900 men, excluding an additional *Feldersatz* (field replacement) battalion. [134] The German line infantry division's TOE varied slightly depending on the period it was created or 'wave'. However the first major organisational change from the 1939 structure occurred in the Type 44 and the *Volks Grenadier* divisions, both well outside the scope of Operation Barbarossa. [135] A first wave German infantry division was very heavily armed and included 435 LMG-GPMGs, 112 HMGs, 1189 horse teams, 516 trucks (and 237 lighter transports), 72 AT guns, 84 50mm mortars, 54 81mm mortars,

20 75mm artillery pieces and 54 105-150mm artillery pieces. The German infantry division was particularly strong in infantry weapons. These included particularly well-armed infantry squads (each with a MG34 GPMG), 75-150mm infantry guns and AT guns. In addition it was more mobile than Soviet rifle divisions or other Axis infantry divisions because it contained more motorised transport. The anti-tank battalion and the regimental anti-tank companies were fully motorised, while the reconnaissance and signal battalions were almost fully motorised. The division also included over 490 motorcycles, which were in addition to the 753 motor vehicles above.

A typical Finnish infantry division in 1941 contained approximately 14 700 men. Its equipment included 432 LMGs, 108 MMGs, 1338 horse teams, only 148 trucks and 20 light transports, 24 AT guns, 36 81mm mortars, 24 75-84mm artillery pieces and 12 105-155mm artillery pieces. [136] The Finnish infantry division was not very mobile and generally lacked all types of heavy infantry weapons (AT guns and infantry guns). In addition shortages meant that each division had only 12 105-155mm heavy cannon and heavy howitzers. Nevertheless the numerous Finnish infantry were themselves well equipped and supplied. In addition, and very importantly, the nature of the local terrain largely neutralised any disadvantages due to lack of mobility: in many instances horse transport proved superior to motor transport which had difficulty operating in the hostile Karelian terrain.

A typical Rumanian infantry division in 1941 contained approximately 17 500 men. Its equipment included 402 LMGs, 148 MMGs, 950 horse teams, only 126 trucks and 27 light transports, 30 AT guns, 60 60mm mortars, 21 81mm mortars, 54 47-75mm artillery pieces and 16 100mm artillery pieces. [137] The Rumanian infantry were themselves reasonably well equipped, but the division was not very mobile and lacked heavy infantry weapons. Most critical was the lack of any decent medium to heavy artillery: each Rumanian infantry division had only 16 100mm howitzers as their heaviest artillery weapons. The bulk of the remaining artillery pieces were light 75mm weapons. This lack of heavy artillery, and their relative immobility, severely curtailed the usefulness of the Rumanian infantry divisions in 1941, and made their attacks against entrenched or fortified

Soviet positions very costly (as happened in the battle for Odessa). Although the Rumanian infantry divisions were large, their lack of heavy weapons and motorised transport meant they were probably the weakest pure infantry divisions possessed by the major Axis powers participating in Operation Barbarossa.

A 1940-41 Italian infantry division was authorised approximately 14 300 men. Its equipment included 270 LMGs, 80 MMGs, 1000+ horse teams, only 86 trucks, 24 AT guns, 126 45mm mortars, 30 81mm mortars, 32 65-75mm artillery pieces and 12 100mm artillery pieces. [138] The Italian infantry division was not at all mobile, generally lacked all types of heavy infantry support weapons (AT guns and infantry guns), and suffered from a severe lack of medium to heavy artillery. In addition, for some reason known only to the Italians, their division structure was binary as opposed to triangular. This meant there were only two infantry regiments per division as opposed to three, and experience had shown well before WWII that the triangular divisional structure was much more flexible, resilient and self-supporting in prolonged combat. [139] All in all the Italian infantry division was probably the weakest Axis infantry division in 1941: even weaker than the average Rumanian infantry division (above). This is probably why none were committed to support Operation Barbarossa; or at least not in the form above. The Italians did dispatch three divisions to the East front in 1941. These were two semi-motorised (also called truck-borne) divisions and one of the more elite *celere* (cavalry or mobile) divisions. Both these division types were considerably smaller than the pure infantry division and struggle to meet any criteria to be classified as divisional sized combat units.

The 1941 type B ‘standard’ Japanese infantry divisions were very large formations. They contained approximately 20 000 men, 382 LMGs, 76-112 MMGs, 2290 horse teams (approximately 8000 horses), 22 AT guns, 340 ‘grenade dischargers’ (50mm Type 89 mortars), and 66 70-75mm artillery pieces. [140] The type A ‘strongest’ Japanese infantry divisions contained approximately 24 600 men, 410 LMGs, 114 MMGs, 18 AT guns, 450 ‘grenade dischargers’, 72 70-75mm artillery pieces and 12 105mm artillery pieces. [141] Generally the Japanese army opted for large divisions with relatively light weapons and little motorisation. In the west this (Japanese) decision has traditionally been attributed to the more hostile jungle terrain

that the Japanese army planned (and trained) to operate in during WWII. However this assumption ignores where the bulk of the Japanese army was actually deployed before and during WWII: specifically occupied China and Manchukuo (Manchuria). In these theatres all types of heavy mortars and artillery, AT weapons and all types of motorised vehicles would have been greatly appreciated (especially against the Soviets). Ultimately the scarcity of heavy artillery, any decent AT weapons, motorisation, and heavy infantry weapons in general, were factors in the rapid Japanese defeat at the hands of the Red Army in Manchukuo in 1945. It is difficult to avoid the conclusion that the lack of heavy weapons and motorised vehicles in Japanese infantry divisions was principally due to the lack of equipment in the Japanese arsenal throughout WWII. [142]

In 1942 US Army infantry divisions were authorised approximately 15 500 men. By 1943 US Army infantry divisions were reduced to approximately 14 300 authorised personnel. They also contained 157 MMGs, 236 HMGs, 2 012 motor vehicles (fully motorised), 57 AT guns, 90 60mm mortars, 54 81mm mortars and 66 105-155mm artillery pieces. [143] US divisions were unique in one respect: the TOE of American units often corresponded to their actual strength (except for units in prolonged combat), and they also exceeded their TOE far more often than any other WWII combatant. However these figures are illusionary because they do not include three additional ‘separate’ battalions which were normally attached to US infantry divisions when they went into action. These included a full tank battalion (authorised 25 M5 or M24 light tanks, 60 M4 medium tanks and 6 M7 self-propelled howitzers), a self-propelled tank destroyer battalion (with 36 M10, M18 or M36 tank destroyers), and a light AA battalion. [144] This meant that from 1943 the average US infantry division had around 127 fully tracked AFVs in direct support. To get this in proportion the reader should note that this was more than the number of fully tracked AFVs authorised in a 1944 German panzer grenadier division, and more than many late 1944-45 panzer divisions actually had. [145] A US infantry division with its tank support was well and truly a divisional sized combat unit.

When discussing the real strength of any western allied divisions in WWII, one really needs to use the term ‘division slice’. Division slice is

military jargon to indicate a force's true strength. It is essentially calculated as the total force strength in the field divided by the number of divisions. It includes non-divisional units such as separate tank battalions and corps artillery regiments, which were normally attached to or supported the division in action. US forces had by far the largest average divisional slice of any of the combatants in WWII. The 60 odd US divisions in Europe in 1944 had a divisional slice of around 40 000 men each in the battle area: around 15 000 with the division itself (armoured and airborne divisions had considerably fewer), 15 000 in combat support and service units, and 10 000 in communication zone forces. [146] In comparison, by 1944 German line infantry divisions had shrunk to an authorised strength of approximately 12 400 men. In addition German divisions had a divisional slice in Western Europe of only 14 900 men on 1st June 1944. [147]

Finally, in 1941 a UK infantry division comprised approximately 17 300 men, 819 LMGs, 48 MMGs, 158 motor vehicles (fully motorised and excluding APCs), 48 AT guns, 162 2in mortars, 56 3in mortars and 72 87.6mm artillery pieces (25pdrs). [148] This meant the large British army infantry division had well-armed infantry, was a very mobile formation and had strong artillery support with three field artillery regiments. However, direct artillery support for attacking infantry in the form of infantry guns was not present, and the division needed medium to heavy artillery support from corps artillery units to destroy the heaviest enemy entrenched or fortified positions. By 1944 the British army infantry division was even more powerful: it was authorised over 18 300 men and its divisional slice was similar to US divisions above (i.e. slightly greater than 40 000 and often included additional armoured units).

So bearing all the above in mind, what conclusions can we draw regarding the common perception and expectation of a divisional sized combat unit? If we display the key information above, and take the average personnel and equipment in the various combatants' divisions, we get the following.

Divisional Comparisons, 1941										
Rifle-Infantry Division	Personnel	LMG-GPMG	MMG-HMG**	Motor Vehicles	Horse Teams	AT Guns	Mor < 61mm	Mor > 61mm	Art < 90mm	Art > 90mm
Soviet (pre June 41)	14500	392	166	607	1100	54	84	66	34	44
German*	16900	435	112	753	1189	72	84	54	20	54
Finnish	14700	432	108	168	1338	24		36	24	12
Rumanian	17500	402	148	153	950	30	60	21	54	16
Italian	14300	270	80	86	1000	24	126	30	32	12
Japanese (type B)	20000	382	112	150-200	2290	22	340		66	
US (1943)^	14300	157	236	2012		57	90	54		66
UK	17300	819	48	2158		48	162	56	72	
Average	**16188**	**411**	**126**	**764**	**983**	**41**	**118**	**40**	**38**	**26**

* LMGs were MG-34 GPMGs with considerably more firepower than contemporary LMGs: the only modern day squad GPMG equivalent in service.
^ Does not include 243 Browning Automatic Rifles (BARs). LMGs shown are Browning .30in MGs
** Excludes MGs used primarily as AAMGs

Thus when a 'divisional sized' combat unit is being described or mentioned it is reasonable for the reader to expect a combat unit with a minimum of 12-14 000 personnel, 250-350 LMGs, 80-100 MMG-HMGs, 400-500 motor vehicles, 700-800 horse teams, 25-35 AT guns, 70-90 small infantry mortars, 25-35 large mortars (greater than 61mm), 25-35 artillery pieces less than 90mm in calibre, and 15-25 artillery pieces greater than 90mm in calibre (a total of at least 40-60 artillery pieces excluding AT guns). A division just meeting this criterion would be relatively small and weak compared to most of the divisions listed above, but could still reasonably be described as a WWII divisional sized combat unit.

The statement above regarding the minimum resources in a divisional sized combat unit becomes even more critical if we are talking about the actual personnel and equipment present in a 'division' on the battlefield at any point in time. Far too often divisional sized combat units are said to have been present when in fact they were divisions in name only: their actual and even authorised levels were far below what one would expect from a divisional sized combat unit. This was especially the case for German units from 1942 onwards and Soviet units from the very beginning of the war. Both German and Soviet divisions progressively shrank as the war went on and their manpower shortages became more and more critical. By 1945 the average Red Army rifle division was down to an actual strength of only 4-5000 men. [149] By western standards this was akin to a regimental sized combat unit and yet the Red Army is commonly credited

with having close to 600 ‘divisions’ at war’s end. When the US or Commonwealth forces refer to a division during WWII, it was almost always a truly divisional sized combat unit. [150]

The above discussion applies primarily to rifle and infantry divisions. Obviously divisions are structured for their primary mission, so armoured, cavalry, mountain and airborne divisions varied tremendously in their TOE and actual levels. Nevertheless the above analysis relating to ‘what is a divisional sized combat unit?’ applies to the large majority of divisions mobilised during WWII.

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2) Measuring Whether a Combat Unit can Reasonably be Called a Divisional Sized Combat Unit

Any division includes personnel and equipment. The equipment can be further divided into transport and support equipment, and weapons. When considering the size of a combat unit it is very important to not only include numbers of personnel but also the amount and type of equipment present. An analysis based purely on authorised or actual personnel is misleading because it fails to take into account the ‘size’ of the biggest weapon systems in the division or the division’s internal support infrastructures. For example, a US 1943 infantry division was authorised 14 253 men while a US 1943 armoured division was authorised only 10 937 men. However the latter had 2 653 motor vehicles (including 501 armoured halftracks), 263 tanks and 54 self-propelled howitzers: altogether a much heavier and often more powerful division than its compatriot infantry division. [151]

Upon analysing the weapon types in most divisions it quickly becomes apparent that certain weapon types predominate in determining its effective size. These are weapon types that are either available in very large numbers (such as MGs and mortars) or that require a large amount of support and transport (such as artillery and tanks). All types of artillery (especially medium to heavy artillery) and tanks require large amounts of support compared to most other weapons. They consume prodigious amounts of ammunition, fuel, spare parts, and transport, and require disproportionate

amounts of support personnel. Naturally they made the division far more lethal and able to inflict more damage with minimal losses, compared to divisions with fewer of these ‘heavy weapons’.

In deciding what resources to include in determining the size of the division, the following are included: total personnel, all types of MGs, all types of mortars, all major transport types (excluding motor cycles) and all types of artillery (excluding AA artillery). Motor cycles, AA artillery, AT rifles and armoured reconnaissance vehicles are excluded because they generally had little effect in increasing or decreasing the overall size of the division. They were either very light equipment requiring little support or were heavy weapons available in limited numbers. For example, AA guns larger than HMGs were comparably few and far between in WWII divisions, and are hence excluded even though they required substantial support to function effectively. On researching the material for this book, it was found that AA weapons in the divisions listed in the previous section contributed on average less than 1% to the overall division’s size. [152] This was because of the rarity of AA artillery within the divisions themselves: apparently the vast majority of AA defence was provided by AA units attached to divisions from corps and army level.

In determining the ‘size’ of a WWII division, the following equation is used.

$$Div_{Size} = Per + (6*LMG) + (10*MMG) + (8*MV) + (4*HT) + (30*ATG) + (8*LMrt) + (30*HMrt) + (60*LArt) + (100*MArt) + (60*Tanks)$$

Where:

Per is the number of personnel in the division.

LMG is the number of LMGs and GPMGs (General Purpose Machine Guns) in the division.

MMG is the number of MMGs and HMGs (Heavy Machine Guns) in the division.

MV is the number of motor vehicles, excluding motor cycles, armoured cars, APCs and tractors (prime movers) in the division.

HT is the number of horse teams in the division (using 3.5 horses per team if only total horses information available).

ATG is the number of artillery type anti-tank guns in the division.

LMrt is the number of mortars with calibre less than 61mm in the division.

HMrt is the number of mortars with calibre greater than 61mm in the division.

LArt is the number of artillery pieces with calibre less than 90mm in the division.

MArt is the number of artillery pieces with calibre greater than 90mm in the division.

Tanks is the number of light to heavy tanks included in the division, but only if the division contains a tank or armoured battalion. Note the proviso on tanks: tanks are included only if tanks formed a significant component of the division. Many divisions contained a few light tanks or tankettes for reconnaissance work, but these were usually few in number.

The above equation enables a practical, realistic and quantitative assessment to be made on whether a 'division' was truly divisional sized, was simply a 'very small division', or was really masquerading as a division. The equation importantly includes the support infrastructures (total personnel and transport) as well as the significant weapon types. The above equation still attributes 40-50% of the division's size purely to numbers of personnel. However it now also takes into account all types of transport infrastructure (typically 20-30% of the division's size), artillery (typically 10-20% of the division's size) and other significant weapons.

It is very important for the reader not to make the mistake of using the equation above to assess the overall combat power of any given division in

WWII. In order to assess the overall combat power of a division, the OCPCs (Overall Combat Power Coefficients) of all the weapons in the division are required, as well as the ROCP (Relative Overall Combat Proficiency) of the force at that time. [153] Inclusion of these factors shows that relatively small divisions sometimes had a disproportionately large amount of combat power. Naturally they also show that many poorly equipped and trained 'small divisions' were even weaker than one would expect. A sophisticated computer based military simulation should calculate the actual overall combat power of each combat unit continuously. It fulfils the millions of calculations required to take into account weapon OCPCs, force ROCP, combat unit size changes (resource losses and gains), readiness losses and gains, and supply state for each time increment being simulated. For a simulation the size of Operation Barbarossa this calculation should be resolved each (simulated) day or less to enable maximum realism.

Applying the size equation to the minimum sized combat unit that can be reasonably called 'divisional sized' (from the previous section), we get a value of 28 540. This assumes a combat unit should have: a minimum of 13 000 personnel, 300 LMGs, 90 MMG-HMGs, 450 motor vehicles, 750 horse teams, 30 AT guns, 80 mortars less than 61mm calibre, 30 mortars greater than 61mm calibre, 30 artillery pieces less than 90mm calibre, and 20 artillery pieces greater than 90mm calibre (a total of 50 artillery pieces excluding AT guns), to be reasonably called 'divisional sized'.

In the FILARM model this will be referred to as the **Minimum Divisional Size (MDS) value and will be set at 28 540**. In addition, division and brigade designated combat units in the various FILARM-PILARM models will often be expressed as a percentage of the Minimum Divisional Size (MDS) value, in order to assess their true size. Applying the size equation and MDS value to the typical rifle-infantry divisions discussed in the previous section, we get the following results.

Divisional Comparisons, 1941		
Rifle-Infantry Division	**Size**	**% of MDS**
Soviet (pre-June 41)	38480	135%
German	42462	149%
Finnish	29508	103%
Rumanian	33266	117%
Italian	27156	95%
Japanese (type B)	41312	145%
US (1943)	44348	155%
US (1944, w typical tank support)	51968	182%
UK	48694	171%

As we can see the Minimum Divisional Size (MDS) value represents a relatively small division by comparison to most WWII divisions. Significantly only the Italian 1940-41 infantry division falls below the MDS value; all other units are above the MDS value with many well above. [154] This underlines the fact that combat units well below the MDS value should not be called 'divisions' simply because of their historical designations. They were usually designated 'divisions' historically because it suited the political, propaganda and morale agendas of the relevant powers at the time. Then as now, it led to incorrect and misguided perceptions of military strengths. If historically designated divisions are used to describe military campaigns and impartial objectivity is desired, then great care should be taken to stress the actual size of the divisions which took part.

Another use of the MDS value is to test the term 'division equivalent' which is also common in WWII literature. In most current accounts of WWII battles and campaigns, two separate brigades or three separate regiments are usually considered to be a division equivalent. If this was the case we would expect the separate brigades and regiments in question to have had a minimum size value of approximately 14 300 and 9 500 respectively: around a half or a third of the MDS value. In fact the vast majority of brigades and regiments operating in WWII were nowhere near these minimum size values: two or three of them were generally not a realistic division equivalent. [155] This was primarily because separate brigades and regiments did not contain the heavy weapons (especially artillery) or the support infrastructures that existed to support the brigades

and regiments within a division. As we shall see in the Soviet FILARM model, this was particularly true for all types of Soviet rifle and tank brigades mobilised in the second half of 1941.

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[133] For some authorities reporting on the history of a war or military campaign this might suit their agenda. This technique is often used to support statements about numbers of enemy troops. For example, until quite recently histories of WWII stated or implied that the Western Allied forces didn't have a significant numerical superiority over the German Army in France and Italy from 1943-45. This was (and occasionally still is) based around the statement that "the Germans fielded a similar number of divisions". In fact, detailed analyses of all US and Commonwealth campaigns from 1942 onwards (starting at El Alamein in 1942) reveals the Allies consistently enjoyed a superiority of 2-5 to 1 in overall manpower, and often much higher in terms of tanks, guns and aircraft. The only time this balance changed was for brief periods on local front sectors (such as the first week in the Ardennes during the German Ardennes counter-offensive in December 1944).

[134] A. Buckner, The German Infantry Handbook, 1939-1945, Schiffer Military History, Atglen, PA, 1991, pp. 14 and 15.

[135] The principal changes in the Type 44 division were that the number of battalions in the infantry regiments was reduced from three to two, and that the reconnaissance battalion was replaced by a fusilier battalion. G.F.Nafziger, The German Order of Battle, Infantry in WWII, Greenhill Books, London, 2000, p. 25.

[136] Refer Volume IVA and IVB - 'The Axis Allied Land and Air Resource Models: the Finnish, Slovakian, Hungarian, Rumanian and Italian Forces Involved on the Eastern Front in 1941', the Finnish FILARM model for details.

[137] Ibid, refer to the Rumanian PILARM model for details.

[138] Ellis, World War II, A Statistical Survey, Facts on File Inc, New York, 1993, p. 209. The so called 'North Africa infantry divisions' had a slightly reduced TOE.

[139] Italian infantry divisions did have a Blackshirt Legion attached with two battalions. Maybe this was viewed as the third regiment of infantry by the Italian army planners? However the Blackshirt units were essentially fascist militia which appear to have been attached to the division to enable greater political influence and control, rather than to enhance the combat power of the division. As such the Blackshirt Legions were poorly supported, poorly integrated and relatively poorly trained. The overall effect of the Blackshirts on the division appears to have been detrimental at worst, and insignificant at best.

[140] The Japanese also fielded heavier mortars such as the 81mm Model 99 and the 90mm Type 94 mortars. However both these weapons were built in very limited numbers and don't appear to have been included as standard in the TOE's of Japanese infantry divisions.

[141] The Japanese categorised their forces under three headings: 'A' strongest, 'B' standard and 'C' special. TOE info from J.Ellis, World War II, A Statistical Survey, Facts on File Inc, New York 1993, p. 212.

[142] Another very strong indicator of the lack of motorisation and support for heavy weapons in the Japanese army is the fact that the average divisional slice (see note below) for divisions in the Pacific was only around 25 000 in 1941. This means there was very little non-divisional support infrastructure in the Japanese army in 1941. J.F. Dunnigan, A.A. Nofi, The Pacific War Encyclopedia, Checkmark Books, New York, 1998, p. 397.

[143] J. Ellis, World War II, A Statistical Survey, Facts on File Inc, New York, 1993, p. 220.

[144] The US formed 65 so called 'separate' or 'independent' tank battalions in WWII and of these 39 fought in Europe from 1944, mostly attached to US infantry divisions. In May 1944 there were 30 'separate' tank destroyer battalions in England available for the Normandy campaign, of which 19 were self-propelled (with M18s and M10s). S. Zaloga, P. Sarson, Sherman Medium Tank 1942-1945, Osprey Military, Osprey Publishing Ltd, London, 1993, pp. 23 and 24. Also S. Zaloga, J. Laurier, M18 Hellcat Tank Destroyer 1943-97, Osprey Publishing Ltd, Oxford, UK, 2004, p. 15.

[145] In April 1944 a panzer division's panzer regiment was authorised 79 Panthers and 101 Pz IVs (including all staff company HQ tanks). However very few panzer regiments ever reached full strength and most operated well below full strength. This was especially true after June 1944. In late 1944-45 the panzer regiment's two tank battalions had reduced TOEs of only 48 tanks each (with 8 more in the panzer regiment staff company). E. Lefevre, Panzers in Normandy Then and Now, Battle of Britain Prints International Ltd, London, 1990, p. 9. Also T.L. Jentz, Panzer Truppen: Volume 2 1943-1945, Schiffer Military History, Schiffer Publishing Ltd, Atglen, PA, 1996, pp. 153-169.

[146] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 32. The 40 000 figure does not include approximately 20 000 men in the USA (in training, hospitals, HQ personnel etc), also part of the division. J.F. Dunnigan, A.A. Nofi, The Pacific War Encyclopedia, Checkmark Books, New York, 1998, p. 396.

[147] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 32. Also J.Ellis, World War II, A Statistical Survey, Facts on File Inc, New York, 1993, p. 204.

[148] J. Ellis, World War II, A Statistical Survey, Facts on File Inc, New York, 1993, p. 217.

[149] In Operation Bagration in June 1944, the average participating Red Army rifle division had approximately 6 000 men. This was after they had been brought up to strength for the major Bagration offensive (from an average strength of around 4000 men). However, no fewer than 118 rifle divisions were available for the operation. S. Zaloga, Bagration 1944, Osprey Military, Campaign Series, London, 1996, p. 27.

[150] Sophisticated military simulations exist of the probable outcome of a military campaign between the Red Army vs. US and Commonwealth forces in Germany-Czechoslovakia-Austria-Hungary in May-June 1945. This scenario (sometimes called the 'General Patton' scenario because there is evidence Patton saw it as an opportunity) envisages hostilities breaking out between the former allies over territorial rights in Europe or-and Stalin not being satisfied with only occupying East Germany. Despite the common perception that the Red Army was an "unstoppable juggernaut" in 1945, the outcome of these simulations almost always ends in a Red Army defeat. The principal reasons for the Soviet defeat (in the simulations) are the fact that the far more numerous rifle divisions were barely at regimental strength with little prospect of replacements, the massive Western Allied air superiority that quickly develops, and the relatively poor Supply Distribution Efficiency (SDE) in the Red Army compared to the Western Allied armies (exacerbated by the Soviet's inability to replace motorised vehicle losses). It is probable that the Soviet High Command was aware of these factors, especially

the shortages of manpower, which contributed to their willingness to settle for less than they had fought so hard (and hoped) for.

[151] J. Ellis, World War II, A Statistical Survey, Facts on File Inc, New York 1993, p. 220.

[152] The UK infantry division listed above was the only exception: it contained a light AA regiment with 48 40mm AA guns in 1941. From the divisions listed, only the Soviet pre-war rifle division was authorised AA weapons greater than 45mm calibre: it was authorised four 76mm AA guns.

[153] Refer Volume I, Part II 2. – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC)' for details on calculating weapon OCPCs. Also refer Volume V - 'Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces on the East Front during WWII'.

[154] This goes some way to explain the poor performance of Italian infantry divisions during the invasion of Albania in April 1939, and during the Italian invasion of Greece from Albania in October-November 1940.

[155] The only consistent exception to this was the WWII British armoured brigade which was usually the armoured portion of an armoured division.

Part II
The Methodology Used for Analysing Weapon System Effectiveness, and the Structure of the 1941 Soviet and Axis Resource Database

1. The Database Resolution Level

For the largest and costliest military campaign in history involving many millions of personnel, hundreds of thousands of vehicles and heavy weapons, and thousands of combat units, the Resource Database cannot practically go down to individual soldier and small arms level. In addition the detailed variations in the internal structure of every small combat unit cannot be fully detailed as there were simply too many of them.

As late as the 1980s, the magnitude of Operation Barbarossa has dictated that most military simulations of this campaign went down to only division and brigade level. This was particularly true for manual map based simulations. [157] This means entire divisions were represented as single manoeuvre units with one set of numbers representing 10-20 000 men and thousands of heavy weapons. Individual divisions and brigades were the defined resource entities available to that side. In military simulation jargon we would define the ' <u>database resolution level</u> ' of these simulations as brigade level, and the smallest defined resource entities or ' <u>database units</u> ' as brigades.

Even today most computer based simulations of Operation Barbarossa only go down to brigade level, although a few have attempted to go down to regimental level. Some existing operational level simulations (relating to the East Front in 1941) have a database resolution down to battalion and occasionally company level, but they usually only simulate particular operations within a limited geographic area and over a period of weeks. Ultimately the degree of realism achievable in any military simulation is proportional to the simulation's database resolution level. However it must be borne in mind that this is still only one of many factors contributing to the eventual realism of the simulation. [158]

The very ambitious goal of 'Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation' is to go much further than even company level. The objective is to create a

Resource Database with a database resolution level down to individual vehicles, heavy weapons, and small self-contained personnel based entities (such as infantry squads, cavalry squads and combat engineer squads). Heavy weapons in this case include anything equal to or heavier than a light machine gun (LMG).

There are five very important reasons for selecting this level of database resolution:

i. **The 'squad' is a suitable level to use because during WWII the squad was normally the smallest tactical manoeuvre unit on the battlefield** .[159]

   The crew of individual heavy weapons larger than a HMG are also of similar size to a squad, and able to function similarly.

ii. **The historical TOE information available for WWII is largely structured down to this level** .

   This implies that when staff officers and high commands thought up new TOEs for organisations to fulfil particular missions, they never seriously thought in terms of resource combinations below this level.

iii. **Software exists today which enables the continuous tracking of millions of individual database resources over time and space, with each resource being affected by individual external factors** .

   These factors include combat, movement, logistical supply, terrain and weather. The speed of PCs today enables us to create this 'monster', and once it is created we can concern ourselves with day to day operational decision making. We do not have to execute the millions of calculations each turn to determine the change of state of each individual resource over time. This latter consideration is the main limitation on even the largest and most sophisticated board based military simulations.

iv. **The true impact of individual weapons and weapon types on an armed force's overall combat power can be determined** .

At database resolution levels higher than company level, the effect of one side having superior weapons (and superior numbers of weapons) is very difficult to ascertain. Weapon effects are treated in an abstract fashion, and any weapon effects usually manifest themselves in estimates of higher attack and defence values in the basic database unit. These global type estimates tend to be very inaccurate and in many cases are simply the results of 'educated' guesswork. They don't consider in detail the true relative combat power of individual weapons or their actual distribution within the database unit.

For example, in military simulations with a database resolution level down to only brigade level, the combat power of panzer or armoured divisions is most often tied directly to the number of tanks in the unit. Yet in these divisions 50-80% of their combat strength resides in motorised infantry, artillery, engineer, reconnaissance and other support units, and not simply armour. This is particularly the case in a defensive posture or in the exploitation phase of a breakthrough. The full impact of weapon effects on determining each side's Relative Overall Combat Proficiency (ROCP), is discussed in Volume V on combat proficiency. [160]

v. **This level of database resolution allows us to create a fully integrated model that tracks the availability of resources resulting from that country's war and mobilisation effort** .

In many WWII histories and military simulations, a country's war effort is credited with producing x number of divisions and x number of other military organisations, without any real analysis of what was actually in those units. A so called 'division' could have historically been a number on a map representing anything from a few thousand scraped together and ill equipped militia, to a Waffen SS panzer division with close to 20 000 men and a great deal of very lethal equipment. It is always misleading when historians talk of combat power or numerical strength on a particular front in terms of numbers of divisions.

A database resolution down to the squad level enables the true strength of any military organisation to be accurately ascertained, and enables accurate modelling of the flow of resources into and out of these organisations. Simply creating new divisions will not win a war if the country's war economy and manpower resources cannot fill them to anything like their TOE. Enabling us to accurately ascertain the true nature of the various combat units historically fielded, is the essence and power of the Fully Integrated Land and Air Resource Model (FILARM).

***

1) Database Unit Resources in the Integrated Land and Air Resource Model

The first step in creating the database resources down to individual squad, vehicle and heavy weapon level, is to select an appropriate yardstick or measure on which to base our analysis. The appropriate measure for our purposes is the lethality of the weapon or database unit. The lethality of the weapon or database unit is defined as 'the inherent capability of a given weapon or unit to kill personnel, or to make material ineffective in a given time period'. This capability is inherent in the weapon or unit: it is either independent of training and deployment, or it assumes the training and deployment is the same for all sides. The term we will use to describe this inherent lethality is **Overall Combat Power Coefficient** **,** hence referred to as the weapon's or database unit's **OCPC** **.**

The main focus in determining a weapon's OCPC, is on the inherent ability to inflict all types of personnel casualties and overall equipment damage. At first glance this can lead to apparently odd OCPCs for certain weapon types. For example, many fighter aircraft have a relatively low OCPC compared to most ground units because they are specifically designed to destroy enemy aircraft and gain air superiority. Their ability to inflict general personnel losses on ground troops and destroy most ground based equipment is limited. However their ability to kill aircraft, i.e. lethality against a specific target type, is very high. [161] Similar arguments apply to anti-tank guns, super heavy artillery and many other weapons.

Generally, weapons designed to kill a specific target type will have lower OCPCs but obviously much higher lethality against specific targets. Weapons designed to kill many targets will have higher OCPCs but may be ineffective against certain target types. The reader should always bear this in mind when viewing a weapon or database unit's OCPC.

The task of calculating any weapon's lethality has been approached by several military simulation methodologies, because it is a fundamental first step in attempting to replicate any armed force's overall combat power. These analyses vary from the cursory to the very detailed. On balance, tactical level simulations spend a lot of time and effort on the physical attributes relating to individual weapon lethality, but very little on the inherent lethality of squad level units or combat units of platoon size and above. In addition many tactical level simulations produce attack and defence figures against specific target types, but only for very limited tactical scenarios. Operational level simulations usually only cursorily analyse weapon OCPCs. They mostly present generic values representing a weapon type's inherent lethality, without focusing on the actual weapon details.

What we require is a methodology to enable the inherent lethality (as defined above) of individual weapons (and weapon systems) to be calculated, which includes factors such as weapon range, rate of fire, accuracy, radius of effects and battlefield mobility. At the same time the methodology must enable the calculation of the inherent lethality of individual squads and all types of vehicles, both of which may have multiple heavy weapons.

After reviewing several established methodologies, the one producing results along the lines of what was required, was originally developed for the Dupuy Institute's Quantified Judgement Model (QJM), and (to a lesser extent) the Tactical Numerical Deterministic Model (TNDM). [162] QJM is probably one of the most well-known, tested, reviewed, scrutinised, controversial and criticised combat models designed. In other words, quite acceptable as a starting point for an accurate calculation of a weapon or combat unit's inherent lethality.

However in relation to creating the 1941 Soviet and Axis resource database, this methodology lacks crucial aspects. To name a few: there is no methodology related to calculating lethality of small dispersed units such as infantry squads, the calculated defensive strength for non-mobile weapons (including small units such as squads) is missing, the defensive strength calculation for mobile land weapons (including tanks) is too simplistic, and the entire treatment of aircraft is missing several vital factors. For the purposes of this work, the QJM methodology has been heavily modified. This has mostly taken the form of additional factors not included in the original methodology. In many cases, modification of the basic underlying formula relating to certain factors has also been undertaken. Where appropriate, some of these changes are indicated by foot notation in the following methodology.

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[156] For the Slovakian, Hungarian, Rumanian and Italian forces we only require and will use a Partially Integrated Land Air Resource Model, (PILARM). Partial in this case means a model of only those forces directly involved in Operation Barbarossa and not all the armed services of those countries.

[157] Refer to Volume I, Part I 1. 1) – 'Studying Military History Using Operational – Strategic Simulations - The Evolution of Military Simulations and War Gaming'.

[158] Refer to Volume VI - for more on other factors affecting the realism achievable by a military simulation.

[159] The squad usually had 6-14 men (normally around 10 in an infantry squad) with a leader, independent equipment and ammunition, and (in some armies) individual communication. The term 'section' is sometimes used to describe the same unit, or sometimes a half-squad. For our purposes a section will be used to describe a half-squad. Normally only 'special forces' or other covert groups would conduct independent operations with smaller units than a squad.

[160] Refer to Volume V, chapter and section titled – 'Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces from 1941-1945 – Axis and Soviet Relative Overall Combat Proficiency (ROCP) in 1941 - Weapon Density (WD) Effects on the 1941 German-Soviet ROCP'.

[161] Note, fighter bombers generally have a considerably higher OCPC than pure fighters, but they are no more effective (and are usually less effective) against enemy aircraft.

[162] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985. Also, T. N. Dupuy, Understanding War: History and Theory of Combat, Paragon House Publishers, New York, 1987.

2. Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC)

The methodology for calculating a weapon or unit's Overall Combat Power Coefficient (OCPC) involves two main steps.

The first step involves calculating the individual weapon's inherent offensive lethality. This is essentially the attack strength of the weapon. At this point, the attack strength of the weapon is unmodified by the transport type, housing, chassis or vehicle that the weapon is on. [163] The weapon is not yet considered to be a complete usable 'weapon system' or 'database unit'. There may be multiple weapons in (or on) any given weapons system or database unit (e.g. a tank with multiple weapons). The **individual weapon's inherent offensive lethality** is termed its **Weapon Combat Power Coefficient** , hence referred to as the weapon's **WCPC** .

The second step is to calculate the weapons system or database unit's OCPC by adding up the individual weapon WCPCs (from above), and then including all other factors relating to the individual weapon system or database unit. This then encompasses all the defensive and offensive aspects of the weapon system or unit such as protection, dispersion and mobility. The multitude of additional factors considered in the second step is detailed in the methodology below. The exact procedure for the second step depends on the category of weapon system or database unit. There are three categories of weapon system or database unit considered in this methodology, which are:

- **Non-mobile weapon systems or squads** . These include weapons that are stationary, towed or carried, with no inherent motorised mobility.
- **Land based motorised Mobile Fighting Machines (MFMs).**

- **Aircraft.**

The methodology presented here is generic in that it is applicable to any weapon system. However it is most suitable for weapon systems from the first half of the twentieth century. The results of applying the complete methodology to each country's available weapon systems and combat units in 1941, are presented in the specific volumes and chapters relating to each country's integrated land and air resource model.

***

1) Calculating Individual Weapon Combat Power Coefficients (WCPCs)

The following factors are considered in calculating an individual weapon's WCPC: Rate of Fire (RF), Number of Potential Targets per Strike (PTS), Relative Incapacitating Effect (RIE), Range Factors (RN), Accuracy (A), Reliability (RL), Self-Propelled Artillery Factor (SPA), Aircraft Mounted Weapon Effect (AE), Multi Barrelled Weapon Effect (MBE), and Typical Target Dispersion Factor (TDi).

A weapon's WCPC is given by,

$$WCPC = \frac{RF * PTS * RIE * RN * A * RL * SPA * AE * MBE}{TDi}$$

a. Rate of Fire (RF)

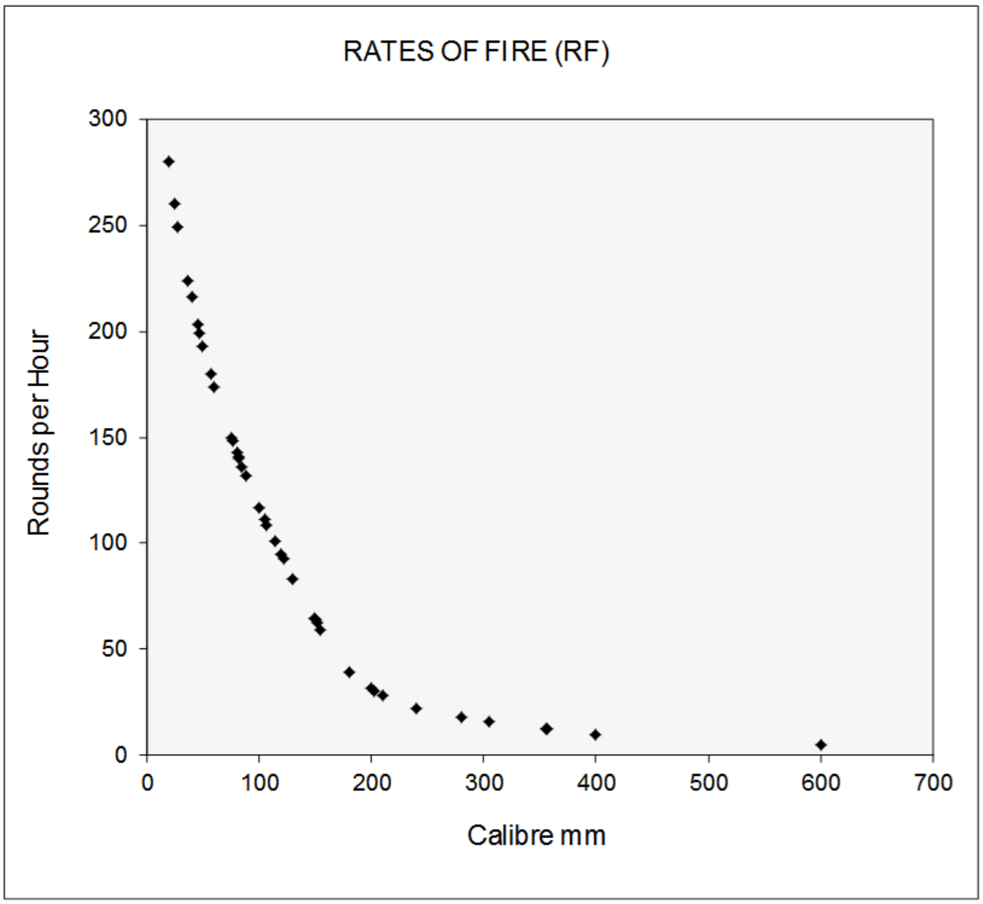
This is the practical number of effective strikes which a weapon, under ideal conditions, can deliver against a target in a given time period. The time period considered is one hour because it permits consideration of sustained rates of fire from large calibre projectile weapons. Logistical ammunition supply constraints are not considered at this point, except for aircraft launched weapons which are limited to one sortie per aircraft per hour.

Rates of fire for non-automatic and non-anti-aircraft (AA) weapons in WWII were principally dictated by the weapon calibre. There were small variations due to breech design, particularly for anti-aircraft weapons, but weapon calibre was by far the dominant parameter. Graph RF shows the relationship between Rates of Fire (RF) (expressed in rounds per hour) versus weapon calibre (in millimetres) for non-automatic and non-AA weapons.[164] This data is used to determine the rate of fire for non-automatic and non-AA weapons once the calibre is determined, for calibres down to 20mm.

Graph RF

Calibre mm (x)	Rate of Fire RpH (y)
20	280
25	260
28	249
37	224
40	216
45	203
47	199
50	193
57	180
60	174
75	150
76.2	148
80	143
81.4	141
82	140
85	136
88	132
100	117
105	111
107	109
114	101
120	95
122	93
130	83
149	65
150	64
152	62
155	60
180	39
200	32
203	31
210	28
240	22
280	18
305	16
355	12
356	12
400	10
600	5

Rates of Fire vs Weapon Calibre, for non-automatic and non-AA weapons



To cover other weapon types the following modifications apply:

i. For **Mortars**, RF = 1.2 x RF value determined from Graph RF.
Mortars are not breech loaded and usually had a higher rate of fire than artillery. Mortars in this case only applies to lightweight, smoothbore, muzzle loading weapons firing a fin stabilised bomb. [165]

ii. For **land based AA weapons with calibre < or = 40mm**, RF = 1.4 x RF value determined from Graph RF.
Land based anti-aircraft weapons less than 40mm calibre in WWII, can be considered semi or even fully automatic. However they were still not machine guns. They mostly used small size magazine clips requiring frequent loading and quickly overheated in a sustained fire role. A quick barrel change as used on some MGs was not an option. For this reason they are not considered to be fully automatic weapons, but do get benefit from being semi-automatic. Sometimes heavy machine guns (HMGs) are regarded as anti-aircraft weapons and called anti-aircraft machine guns (AAMGs). These weapons are really machine guns and are therefore treated as land based automatic weapons (below).

iii. For **land based AA weapons with calibre > 40mm**, RF = 1.2 x RF value determined from Graph RF.
Anti-aircraft weapons greater than 40mm calibre usually had semi-automatic breech systems, which enabled faster loading. In addition, they had larger crews for servicing the gun compared to AT guns or artillery of similar calibre.

iv. For **aircraft launched weapons**, RF = the number of bombs or rockets of a particular type, carried on a bombing or ground attack sortie.

v. For **land based automatic weapons**, RF = 4 x cyclic rate per minute x 1.2 (if belt fed) x 1.2 (if water cooled as opposed to air cooled) x 1.33 (if classified as an MMG or HMG with dedicated crew).

Belt fed MGs maintain higher rates of sustained fire when not stopping for reloads with magazine clips. Water cooled MGs maintain higher rates of sustained fire due to more effective barrel cooling and less frequent barrel changes. Medium and heavy machine guns with dedicated crews maintain higher rates of sustained fire over light machine guns (LMGs) in infantry squads. This is due to the larger MG

crew and more equipment in the HMG-MMG squad, which results in more rapid barrel changes, fewer stoppages, more spare parts, etc. [166]

vi. For **aircraft mounted automatic weapons**, RF = 2 x cyclic rate per minute.

Generally in WWII, aircraft mounted MGs had a higher cyclic rate of fire than most infantry weapons. For example, the Soviet 7.62mm ShKAS MG (*Shpitalny-Komaritsky aviatsionny skorostrelny* or Rapid-firing Aircraft Gun) had a cyclic rate of fire of 1 800 rounds per minute. This was possibly the highest rate of fire of any WWII MG. Similarly, the 12-13mm HMGs and 15-20mm cannon on aircraft also had higher cyclic rates of fire than equivalent land based weapons. The reason is that aircraft only acquire any target for a few seconds at most, and these weapons need to deliver their 'punch' in that time.

The problem is we are considering sustained rates of fire over a longer time period and aircraft mounted automatic weapons are not designed for sustained fire. Apart from ammunition considerations (considered under Aircraft Mounted Weapon Effects below), these weapons quickly overheat and will likely jam if fired for more than a few seconds at a time. They are fired in shorter bursts suited to AA fire and aerial combat. Coupled with this is the nature of air to ground combat. In order to attack anything the aircraft must sortie, i.e. it spends most of its time getting to a position to sustain a fire rate and then only stays for a short time. Even under the ideal laboratory type environment being considered here (which should be common for all weapons), and at times of maximum contact with the enemy, aircraft spend most of their time flying to and from the target and additional time reloading-refuelling. The net result is overall reduced rates of sustained fire compared to continuously available land based weapons.

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b. Number of Potential Targets per Strike (PTS)

In order to establish a basis for comparison of the relative lethality of all weapons, it is essential to establish a standard of target density. This is

because many weapons have the ability to incapacitate more than one enemy per strike (a strike being as defined above). These are often termed area fire weapons as opposed to point fire weapons. A commonly accepted standard for target density is one individual every square metre. Although unrealistic or artificial in terms of battlefield circumstances, this standard allows a comparison to be made of the relative lethality of area fire weapons (mostly using high explosive shells) and point fire weapons (mostly firing non-explosive solid type projectiles).

Individual small arms and light machine guns are limited to one target per strike.

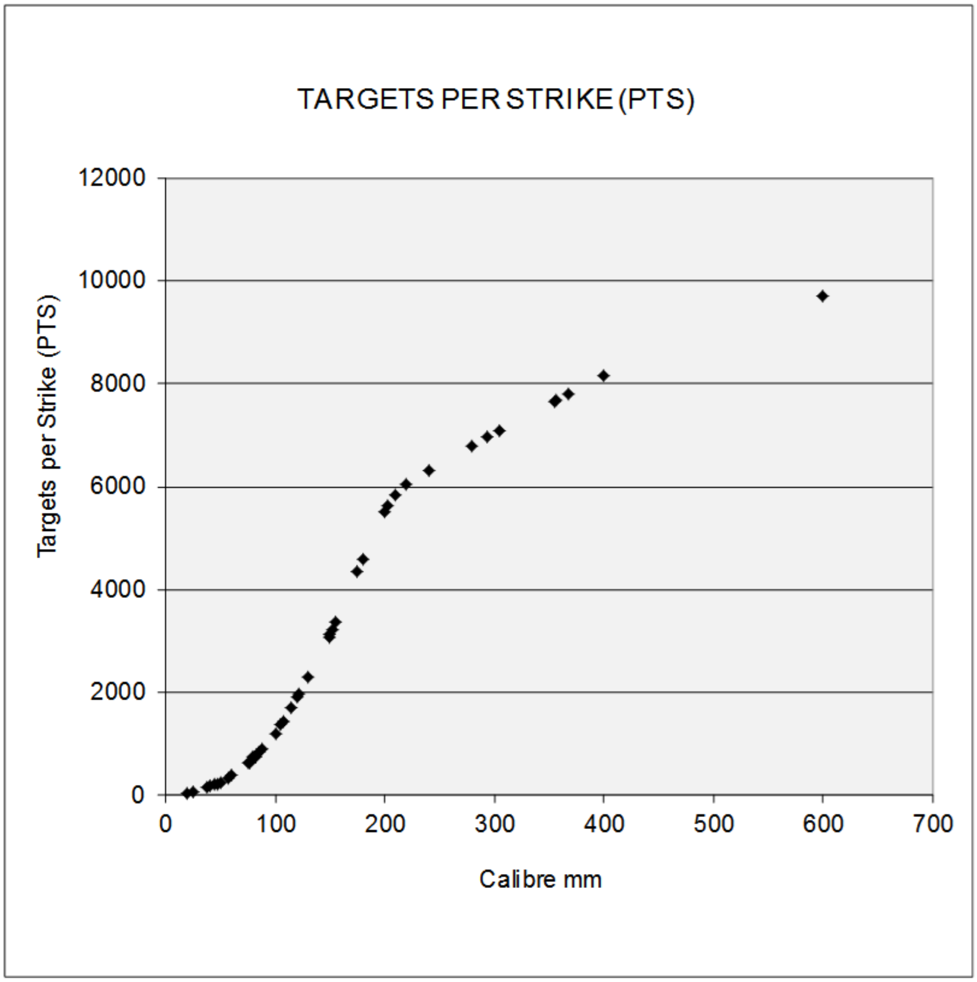
Machine guns with calibre 12-13mm are limited to 1.2-1.4 targets per strike.

Generally, high explosive weapons are considered to hit one person per square metre within the lethal area of burst. Graph PTS shows the relationship between the number of Potential Targets per Strike (PTS) versus weapon calibre (in millimetres) for weapons using high explosive ammunition.[167] This data is used to determine the PTS value for the weapon once the calibre is determined.

Graph PTS

Number of Potential Targets per Strike vs Weapon Calibre

Calibre mm (x)	PTS (y)
20	40
25	67
37	148
40	170
45	208
47	224
50	250
57	325
60	400
75	620
76.2	640
80	735
81.4	747
82	760
85	832
88	910
100	1200
105	1375
107	1435
114	1690
120	1900
122	1975
130	2300
149	3070
150	3130
152	3220
155	3370
175	4358
180	4600
200	5500
203	5620
210	5850
220	6035
240	6300
280	6800
294	6970
305	7100
355	7660
356	7671
368	7802
400	8150
600	9700



The only major modification to the PTS value applies to mortars, specifically:

i. For **mortars**, PTS = 0.7 x PTS value determined from Graph PTS.

This is because the velocity of impact of mortar rounds is considerably lower than similar calibre artillery rounds, as a result of mortars having lower muzzle velocities and correspondingly much shorter ranges. [168]

***

The process for determining the PTS value for rockets and air launched bombs involves an additional step. For rockets the weight of the warhead, and for air launched bombs the total bomb weight, are converted into an equivalent calibre round and then into an appropriate PTS value using Graph PTS.

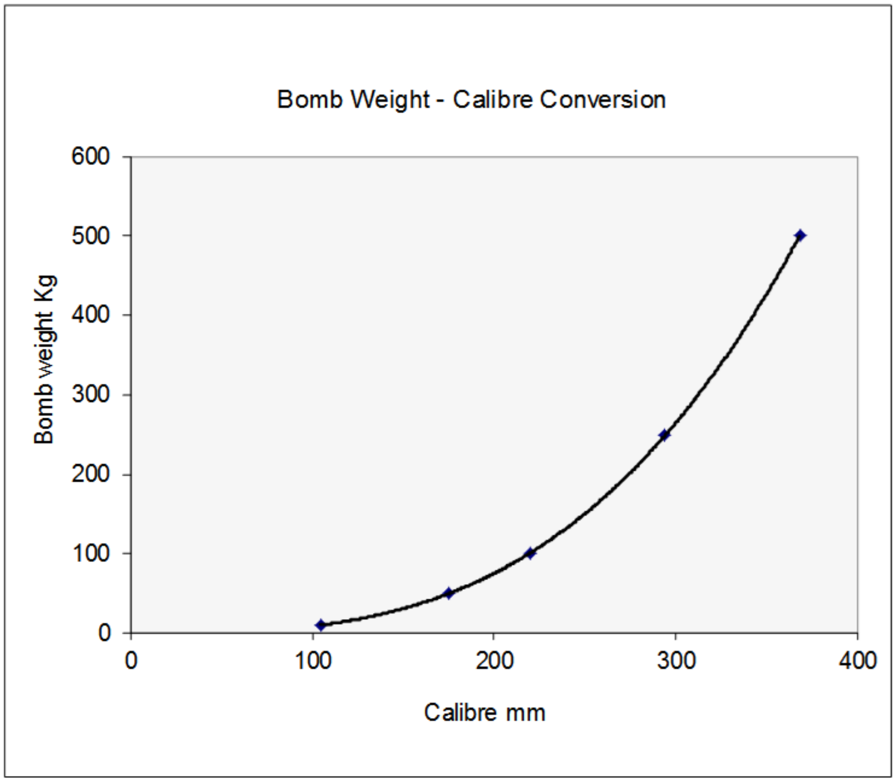
The Soviet BM-8 and BM-13 rockets have warhead weights of 0.5 and 4.9kgs respectively. These equate to PTS values similar to typical 45mm and 122mm gun-howitzers respectively. The German *Nebelwerfer* 35, *Nebelwerfer* 41 and 28cm *Wurfkorper Spreng* have warhead weights of 2.2, 10 and 61kgs, respectively. These equate to PTS values similar to typical 75mm, 150mm and 305mm howitzers, respectively. Rockets also impact at a lower velocity than artillery rounds, but do not suffer the 0.7 adjustment as for mortars because the rocket's body and unused fuel also contribute to the lethal area burst. Note, the rocket's body and unused fuel are not included in the rocket's warhead weight (above).

Graph BW shows the average relationship between air launched bomb weight and weapon calibre. For example, a 100kg bomb (total weight) is equivalent to a 220mm calibre artillery round, so the correct PTS value from Graph PTS is 6 035. Bombs dropped from low altitude would generally have lower impact velocities than artillery, but bombs dropped from medium to high altitude would usually have similar or even higher impact velocities. On balance, air launched bombs do not have the 0.7 adjustment for lower impact velocities.

Graph BW

Average Relationship of Bomb Weight to Calibre.

PTS	Calibre mm (x)	Equiv Bomb Weight Kg (y)
1375	105	10
4358	175	50
6035	220	100
6970	294	250
7802	368	500



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c. Relative Incapacitating Effect (RIE)

Single strikes from some weapons are more likely to be incapacitating than single strikes from others. The Relative Incapacitating Effect (RIE) is the likelihood that a single strike will be incapacitating. RIE is expressed as a percentage probability.

For weapons more powerful than small arms or medium machine guns, the RIE value is always 1. For other weapons the RIE value is as follows:

i. Light and medium machine guns (LMGs and MMGs), and bolt action rifles, RIE = 0.8

ii. Sub machine guns (SMGs), RIE = 0.7

iii. Pistols and revolvers, RIE = 0.6

iv. Hand to hand, RIE = 0.4

Note, hand grenades, flamethrowers and close assault explosive charges are considered to have an RIE value of 1. [169]

***

d. Range Factors (RN)

A weapon's effective range clearly has a direct impact on its overall lethality. Longer range gives a weapon more opportunity to be lethal or incapacitating, and enemies within range are forced to take passive and active countermeasures to defend themselves.

There are two basic approaches to calculating Range Factors (RN).

The first is based purely on the maximum effective horizontal range of the weapon. Weapons such as field artillery are designed to take advantage of firing their projectiles at elevated angles (around 45 degrees), to obtain maximum range. These weapons are designed to be used at long range and against targets unseen by the firing weapon (i.e. indirect fire). The RN factor based on maximum effective range is given by,

$$RN(range) = 1 + \sqrt{0.001 * Max\ \ Effective\ \ Range}$$

where *Max Effective Range* is expressed in metres (referred to as equation (1) below). [170]

From equation (1) we can see the value of RN(range) is always 1 or greater; 1 being the length of a man's arm or 1 metre.

However many weapons such as AT guns, AA guns and tank mounted guns, are usually used in the direct fire mode. These weapons have high muzzle velocities (significantly higher than most field artillery), and are designed for maximum penetration, flat trajectory and reduced time of

flight. Depending on the gun's carriage design, these weapons are capable of similar or even longer ranges than artillery of comparable calibre. However, the weapon data for these weapon types normally lists the 'maximum effective range' to be considerably less than the maximum horizontal range achievable by the weapon if it was firing at elevated angles. This is particularly true for anti-tank (AT) guns which normally fire at very low elevations. The maximum effective range of such weapons is normally considered to be the maximum range that the gun can effectively engage enemy tanks. This 'range' is dependent on muzzle velocity, projectile mass and the optical quality of the gun sight, and is always markedly less than the weapon's maximum horizontal range. Therefore these weapons would be disadvantaged if only equation (1) was used, leading to inconsistent and inaccurate weapon WCPC values.

For example, consider the case of the most famous artillery weapon in WWII, namely the German 88mm FlaK 18/36 or simply the '88' as it became known. The 88 was used against all types of aircraft, was lethal against the vast majority of WWII tanks (even at long range), and was sometimes used as field artillery: "anti-aircraft, anti-tank and anti-social!" as one British officer put it. The 88mm FlaK 18/36 had an effective ceiling (against aircraft) of 8,000 metres, was able to effectively engage enemy tanks out to 3,000 metres (largely due to the outstanding quality of its optical gun sights, designed to engage ground as well as airborne targets), and had an effective horizontal range of 14,815 metres. So which 'range' do we use for calculating the 88's Range Factor (RN)? It is unreasonable to use 14,815 metres because the 88 was least often used as field artillery. It is unreasonable to use 8,000 meters because we are concerned with the 'inherent capability of the 88 to kill personnel, or to make material ineffective in a given time period' and not only its lethality against aircraft. Lastly, it is unreasonable to use 3,000 meters because tanks are much harder to destroy than personnel so the previous point applies, and it would be inequitable to use this range whilst allowing field artillery to use effective horizontal range.

It is apparent that the 'maximum effective range' is very subjective for this class of weapon, and we therefore need to change the parameters by which the Range Factor (RN) is calculated. Regardless of the target, or the

mode of operation in the example above, the two parameters that remain relatively constant are the weapon's muzzle velocity and projectile mass. [171] This leads us to the second basic approach to calculating Range Factors (RN).

For greater consistency of results and increased precision in comparing overall lethality, the RN factor for direct fire, high velocity weapons is based on muzzle velocity and weapon calibre. In this case the RN factor is given by,

$$RN(mv) = 0.007 * \mathit{Muzzle\ Velocity} * \sqrt{0.01 * \mathit{Weapon\ Calibre}}$$

where *Muzzle Velocity* is expressed in meters per second, and Weapon Calibre is expressed in millimetres (referred to a equation (2) below). [172]

To ensure the appropriate formula is applied to any given weapon, the following rules are used.

i. For field artillery, rocket bombardment systems, air launched rockets, hand and rifle grenades, flamethrowers, and AFVs mounting any of these weapons, use RN(range).

ii. For AT guns, AA guns and AFVs mounting any of these weapons, use RN(mv).

iii. For all light and heavy infantry weapons (except those in i. and ii. above), AFVs mounting these weapons, and all aircraft mounted automatic weapons, use an average of RN(range) and RN(mv). These weapon types include HMGs, AAMGs, mortars and infantry guns.

iv. For air launched bombs, use RN(mv), with mv = 250 metres per second. [173]

v. For air launched rockets use the rocket's range in RN(range).

For AFVs it is sometimes unclear what category (as defined above) of primary weapon the AFV carries. Tanks in particular fire at both armoured

and non-armoured targets, and some have low velocity high trajectory guns that are still used as AT guns. If unclear, use rule iii. above.

In some cases information is not available for both the weapon's range and muzzle velocity. In these cases use either formula above to calculate RN. Note, the formulas are deliberately designed to not produce widely disparate results. They are there to produce more refined, consistent and precise comparisons of overall weapon lethality.

***

e. Accuracy (A)

If we assume uniform training and conditions, and precise aiming of a weapon at a given target, then the probability that a single blow from that weapon will hit the target is an inherent quality of the weapon and not of the user. For projectile weapons this is often termed 'grouping' and is carefully measured for weapons such as AT guns and sniper rifles. It is important to understand here that we are not considering weapon optics or other fire control systems (which are considered later), but the inherent repeatable accuracy of the weapon.

Many factors can affect a weapon's inherent repeatable accuracy. These include: muzzle velocity (high velocity weapons tend to be more accurate), weight of projectile (heavy projectiles tend to be more accurate over longer ranges due to the physical laws of conservation of momentum), barrel design, quality and tolerances used in construction, barrel wear, ammunition quality and consistency, and weapon carriage and breach design. Where weapon accuracies at average combat ranges are not included in available literature, repeatable accuracy is principally based on muzzle velocity, weight of projectile and (to a lesser extent) historical performance.

There are some special accuracy issues related to aircraft weapons which need to be considered. Aircraft weapons are divided into 'aircraft mounted weapons' and 'aircraft launched weapons'. Refer to section 'Calculating an Aircraft's Overall Combat Power Coefficient (OCPC)' for definitions of these weapon types. [174] Fixed aircraft mounted weapons are more effective if they are mounted along the centreline of the aircraft

airframe. This is because wing mounted weapons are angled inwards so that fired rounds converge on a point in front of the aircraft. These weapons need more careful mutual alignment and calibration, and the pilot needs to estimate his target distance more accurately when firing. For this reason MG or cannon firing through the propeller hub, or nose mounted on twin engine aircraft, have 0.1 added to their accuracy. Note, weapons firing through the propeller do not receive this bonus: they are more accurate than wing mounted weapons, but they generally have a lower rate of fire and are less reliable (as they are synchronised with the engine).

The Accuracy (A) Factor for air launched weapons, which includes bombs and rockets, depends on the capabilities of the launch aircraft and the most common mission type given to that aircraft type. For example, a bomb dropped from a dive bomber such as a Junkers Ju 87R will usually be much more accurate than the same bomb dropped from a medium to high altitude level bomber such as a Heinkel He 111H-6.

***

f. Reliability (RL)

All mechanical weapons can and will malfunction. This factor provides for such occurrences as misfires, dud ammunition, jamming or any other break down that degrades the overall lethality of the weapon.

Some statistical information on weapon reliability is available for a few of the weapons in WWII, but overall the RL factor is largely a judgemental factor based on known operational experience.

***

g. Self-Propelled Artillery Factor (SPA)

During WWII many artillery pieces, AA guns and AT guns can be classified as self-propelled. These involve mounting a standard weapon on a mobile platform with cross country capability, usually with light side armour protection and sometimes with light overhead armour protection. These weapons and vehicles are fully mobile. They are designed to move as

a self-contained unit, keeping up with other mobile formations. Therefore most self-propelled weapons, along with more heavily armoured tank destroyers and assault guns, are treated as land based motorised Mobile Fighting Machines (MFMs) **(** below). [175]

However some heavy or super heavy artillery also had the ability to move as self-propelled artillery, albeit in a much more limited fashion. These weapons were very heavy, moved slowly and could not generally cross bad terrain. They usually moved on carefully reconnoitred routes, lacked armour protection and usually had ammunition carried on separate vehicles to the weapon carrying 'vehicle'. For our purposes these weapons do not qualify as motorised mobile fighting machines and are classified as non-mobile weapon systems. The mobility in these weapons was essentially to enable more rapid movement to a firing position from a railhead, without having to dismantle and reassemble the gun/howitzer. Such weapons do gain the following benefit:

i. SPA = 1.1, if the weapon has no armour protection.

ii. SPA = 1.15, if the weapon has side or overhead armour protection.

The only weapon which qualifies in this category in Operation Barbarossa was the German 60cm Morser 'Karl' (Gerat 040). The four 'monster guns' available for Barbarossa weighed 124 tons with a road speed of 10km/hr. Note, railroad artillery does not receive the SPA benefit: rail guns are mobile only in a limited sense along friendly rail lines. They do however receive a major benefit in having much shorter set up times (refer below) and high operational mobility.

***

h. Aircraft Mounted Weapon Effect (AE)

Any permanently mounted aircraft weapon systems, which fire high velocity projectiles, have their WCPC values degraded by an Aircraft Mounted Weapon Effect (AE) of 0.25. [176]

Aircraft launched weapons, where the weapons leave the aircraft such as free fall bombs, are not affected by the AE factor (i.e. AE =1). Aircraft launched weapons do however have severe accuracy factors, depending on the type and capability of the launch aircraft, and whether these weapons are guided after launch. For example dive bombers tend to be much more accurate than high altitude bombers. This stems from the aircraft type and not any inherent difference in the bomb accuracy. Note however that heavier free fall bombs are slightly more accurate than lighter ones due to conservation of momentum.

The AE factor may require some explanation. There are several key reasons why aircraft mounted automatic weapons during WWII had degraded lethality, particularly against land targets.

- Aircraft do not carry much ammunition. Most land based vehicles can carry enough ammunition to sustain approximately an hour of combat, but aircraft cannot. In this case logistical ammunition supply constraints on the weapon have to be considered and built into the weapon's WCPC. To illustrate this point let us consider some examples. The Messerschmitt BF109E-4 had 2x20mm MG 151 Cannon and 2xMG 17 Machine Guns. However it only carried 60 rounds per cannon and 1000 rounds per MG. Given the cyclic rate of fire of these weapons the pilot would run out of cannon ammunition after a full 7-9 second burst, while his MG ammunition would enable approximately 50 seconds of sustained fire. Many aircraft carried considerably less MG ammunition than even this. The Hawker Hurricane IIB carried an impressive 12x0.303 calibre Browning Mk2 machine guns, but only 334 rounds per gun. Given the cyclic rate of fire of these weapons (1 200 rounds per minute) the pilot would run out of ammunition after a full 17 second burst. Other similar figures are: the P-47 Thunderbolt -24 seconds, P-51B Mustang -28 seconds, Hawker Typhoon Mk1B -15 seconds (cannon), Focke Wulf Fw190A8 -19 seconds (cannon) and 32 seconds (MGs). If attacking ground targets in a strafing attack, much longer bursts are required than the shorter bursts used in air to air combat. Obviously, even late in WWII aircraft would only have the ammunition for around 2-4 passes, and then its home (hopefully!) .

- Aircraft with unguided weapons were, and still are, relatively inaccurate. By modern standards aircraft in WWII were very inaccurate; particularly against small ground targets the size of a tank. Aircraft had enough trouble hitting a large target such as a factory or battleship. This inaccuracy is over and above the inherent repeatable accuracy of the weapon considered in the Accuracy (A) factor. It stems from the nature of air-ground combat and the state of guided weapon technology at that time.

  When considered objectively, this is not surprising. Against a target protected by light flak or MGs, a WWII fighter-bomber would need to execute a ground attack at speeds above 150mph (241kmh) to have much chance of survival. This relatively low attack speed still equates to a speed of 67 metres per second. A large Panther tank is only 8.86 metres long (including the barrel) and 3.4 metres wide. This means that if the plane was conducting a strafing attack, the tank would remain in the gun sight for just over a tenth of a second. Even if the pilot was to point his aircraft straight at the tank (probably fatal against a heavily protected target like a tank spearhead), he would have at most a few seconds. All this is before we even consider the tank's motion, the terrain around the tank or the turbulent effects of defending flak. This is not just theoretical. Trials on training grounds in England revealed that fighter bombers attacking with salvoes of up to eight rockets at a time, still only had, at most, a 4% chance of hitting a tank. This was without defending anti-aircraft fire and against a stationary target in an open field. [177] Refer to the sections on 'Calculating an Aircraft's Overall Combat Power Coefficient (OCPC)' and calculation of Relative Anti-Armour Value (AT) for aircraft, for further development of this. [178]

- Aircraft mounted weapons spend much less time in service (actually exerting their lethality) than ground based weapons, due to overall aircraft malfunctions. This is in addition to the weapon Reliability (RL) factor considered previously, which only considers the inherent reliability of the weapon itself.

  The problem for aircraft is that any malfunction of non-accessible

parts of the aircraft, including its automatic weapons, usually requires a return to base to fix (provided of course it can return to base). Nearly all the aircraft's components need to be close to 100% operational in order for it to function at all, and certainly for it to function safely. Consider for example a group of tanks moving into battle and one throws a track. In WWII tank crews were trained (and expected) to get out and fix such a problem, even under combat conditions if necessary and if possible. [179] In addition the tank still has all its weapons functioning and is still capable of sustained combat. In relatively short order the tank will usually return to the main group. Now consider the same situation in aircraft. Any problem with a propeller, engine, flight controls or something similar, requires a return to base or the risk of the aircraft's total loss is high. The plane and all its formidable weapons are temporarily out of action. Another simple example is a jammed MG. On a land based MG this normally takes anything from a few seconds to a few minutes to fix. On a fighter-bomber a similar weapon normally takes a return to base and, hence, several hours to fix. [180]

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i. Multi Barrelled Effect (MBE)

The Multi Barrelled Effect (MBE) applies to weapon systems with more than one barrel, but with a common tracking and fire control system. Such weapons have increased firepower over single barrel weapons but obviously this increase is not a simple multiple of the number of barrels. If it were, everyone would simply put as many barrels in one turret regardless.

In reality there are a few disadvantages to multi barrel weapons. Multi barrel weapons are considerably heavier and bulkier than single barrel weapons, which results in slower target acquisition and tracking. Although multi barrel weapons deliver a much higher rate of fire onto a specific target, if the weapon is firing at air it doesn't matter how many barrels are firing. On top of this, any malfunction of one barrel system (such as a feeder jam) affects the balance of the weapon when firing and degrades the performance of the other barrels.

The Multi Barrelled Effect (MBE) factor is calculated as follows: the first barrel has a value of 1, the second of 0.5, the third of 0.33, the fourth of 0.25, the fifth of 0.2, the sixth of 0.19, the seventh of 0.18, etc, to a maximum value of 4.18 for 24 or more barrels. These values are then added to get the total MBE factor for the weapon. [181]

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j. Typical Target Dispersion Factor (TDi)

Historically battlefield weapons have become more and more lethal over time. One might therefore expect casualty rates, measured as a percentage of force present per day, to have increased in modern times. However research shows that in fact the opposite has occurred. The reason for this is that troop formations have become more dispersed over larger battlefields as weapons have grown more effective and lethal over longer ranges. Thus the actual battlefield effectiveness of weapons in producing casualties has been decreased by the presence of fewer targets in a given area: that is to say the dispersion factor has rapidly increased over time.

Additional research has shown that typical dispersion factors on historical battlefields were: ancient armies -1, 17th century - 5, 18th century - 10, Napoleonic wars - 20, American civil war - 25, WWI - 250, WWII - 3000 and 1970s - 4000. [182] These figures are based on the area in square kilometres occupied by a typical 100 000 man army when tactically deployed at that time. Of note is the quantum leap in dispersion factors between WWI and WWII. This was apparently due to several factors, but the main one was a major increase in overall battlefield mobility. Thus since WWII increases in dispersion factor have been only moderate. What all this means is that any weapon's WCPC is a function of time. Thus the same weapon in WWII would typically be 12 times more lethal (if measured as lethal to personnel) if it were operating in WWI.

However upon applying a dispersion factor of 3000 to all WWII weapons, unrealistic and inconsistent results appeared. It quickly became apparent that this was an over simplification and that the dispersion factor is not only a function of time but also a function of weapon type. More

specifically, the dispersion factor is a function of the ‘type of target’ that a particular weapon type would most commonly be used against.

Specific weapons and whole weapon families are usually developed to meet a certain criteria and fulfil specific combat missions. These missions involve different types of target and of course different types of target have widely ranging dispersion factors. This is the origin of the Typical Target Dispersion Factor (TDi), <u>and is specific to a weapon type</u> . [183]

To illustrate this let us examine a few examples. Close range weapons such as grenades are used when the target is approximately 30 metres away or less. They are used in close combat, usually to destroy a ‘nest’ of enemy troops not in line of site and/or in cover. Close combat usually occurs between densely packed troops conducting an assault or defending against an assault. Either way, these weapons are almost always used against targets with lower dispersion factors.

As battlefield ranges increase the number of potential targets increases, but so does the typical target dispersion. Small arms up to HMGs are still going to be used at close range but also to engage targets at typical combat ranges of 300-800 metres. At these ranges the enemy will be more spread out and using any available cover. They may be concentrating for an attack/assault but will still be more dispersed than in the close assault phase. Note, however, that many longer range weapons are actually less effective in close combat and are therefore used less against lower dispersion targets. Hand grenades and SMGs are more useful in close house to house fighting than a 50kg HMG.

At battlefield ranges from 800-1500 metres, weapons can attack even more targets, but the targets will in general be even more dispersed. At this range the enemy would likely be using smoke or/and major geographical obstacles for cover and to hide any initial deployments pending an attack. Weapons capable of effective fire at these ranges are usually not used against very close range (low dispersion) targets at all. For example, heavy AT and heavy infantry guns should avoid being in a position where they are forced to fire at very close enemy infantry, and if being close assaulted these guns are likely already lost. The one thing all the above weapons have

in common is that they are all essentially direct fire weapons, which means the weapon's crew normally have line of sight to the target. Although some weapons above can be used for indirect fire, this is not what they were designed and usually used for.

At battlefield ranges beyond 1500 metres, weapons can attack highly dispersed units in rear areas. Units in rear areas are usually widely dispersed because they need to be in order to protect themselves, and they don't need to concentrate for an immediate attack or defence. In order to attack these targets, indirect fire would normally be required. Artillery, mortars and (to a lesser extent) bombardment rockets are essentially indirect fire weapons. If used correctly they are used to fire at unseen targets at long range. If possible, communication with a forward observer enables them to 'see' the target, but just as often they are firing blind at area targets. This type of target could have low dispersion (such as infantry concentrating for an attack) or infinite dispersion (such as an empty field).

Even if artillery is firing against a dense enemy concentration where the target dispersion is comparable to shorter range weapons, this is not the only target type it will fire against over a period of time. On average artillery will be firing at targets with huge variations in target density. This is in direct contrast to weapons such as hand grenades, rifle grenades, flamethrowers and close assault charges, which are always used against targets with relatively low target dispersion factors.

After reviewing the most common target dispersion for different weapon types in WWII, the following Typical Target Dispersion Factors (TDi) are used to obtain more realistic, consistent and precise comparisons of overall weapon lethality. [184]

- Hand and rifle grenades, flamethrowers and close assault charges - 1500
- All types of direct fire weapons up to 15mm HMGs - 2000
- All types of direct fire heavy weapons heavier than 15mm HMGs - 3000
- All types of primarily indirect fire weapons - 4000

- Aircraft mounted weapons and air launched weapons - 3000
- AFVs depend on the primary weapon carried, and is defined from the above categories.

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2) Calculating a Non-Mobile Weapon System's or Squad's Overall Combat Power Coefficient (OCPC)

So far we have been concerned with the offensive lethality of the weapons in any given weapon system or squad. We now have to consider all aspects of non-mobile weapon systems or squads, including defensive factors, in order to calculate their Overall Combat Power Coefficient (OCPC). These systems include weapons that are stationary, towed, or carried, and with no inherent motorised mobility.

The following factors are considered in calculating non-mobile weapon system or squad OCPCs: Main Weapons Combat Power Coefficient (WCPCs) calculated in step 1) above, Tactical Responsiveness Factor (TRF), Fire Control Effect (FCE), Concealment and Protection Factor (CPF) and Defensive Dispersion Factor (DDF). [185]

For non-mobile weapon systems or squads, the Overall Combat Power Coefficient (OCPC) is given by,

$$OCPC_{Non\ Mobile\ Wpn\ Sys\ or\ Squad} = \left(\sum_{1}^{x} WCPC_{x} * TRF * FCE \right) + \left(CPF * DDF \right)$$

where the (capital sigma) WCPC summation (from 1 to x) is the sum of WCPCs for all weapons in the squad (x = all weapons), or the WCPC of the primary weapon in a non-mobile weapon system (x = 1).

The reader should note that the factors on the <u>left side of the plus sign in the equation are essentially offensive components</u> while those on the <u>right are essentially defensive components</u>. Hence the overall combat power is the sum of the offensive and defensive elements.

***

a. Tactical Responsiveness Factor (TRF)

The TRF factor is a measure of how quickly the weapon system or squad can bring its weapons into action from a transport or mobile state.

Once the typical time into action (in minutes) from a transport or mobile state has been established, the TRF factor is determined using the following,

$$TRF = \left(1/\left(\sqrt[3]{Time\ into\ action, \min}\right)\right) * 1.9$$

Initially, when considering the TRF factor, it would appear that the weight of the weapon was the predominant factor. However it turns out that although the weight is very important, several other vital factors come into play. These include weapon carriage design, transport type, support infrastructure classified as part of the weapon system’s crew, and any systems external to the weapon system which are required to enable the weapon to function effectively.

For example, the German 8.8cm Flak 18/36 weighed almost five metric tons in action. However its design meant it could fire from its wheeled carriage while effectively still in transport mode, or it could (relatively) quickly deploy to its cruciform base. The crew were usually equipped with a dedicated and powerful halftrack which meant they could position the gun rapidly. In addition they could fire at any target in line of site immediately, including aircraft, without waiting for external fire control systems to be set up. In comparison the German 15cm sFH 18 (150mm heavy field howitzer) weighed around 5.5 metric tons in action. The howitzer had to be deployed with split trails moved from their transport bogey in order to be fired. Transport was either motorised or often horse drawn, affecting the speed of deployment. The sFH 18 was primarily an indirect fire weapon, generally too slow and much too valuable to deploy in direct fire mode. This meant that unless the gun was firing blind, a fire control network needed to be set up. On balance the Flak 18/36 would be in action over five times quicker than the sFH 18, even though it had a similar weight in action.

The time taken to set up a fire control network should not be under estimated. This network consists of verified map locations, a radio or field telephone network, contact with authorised and properly located forward observers, and an approved fire plan. Often, setting up a fire control network takes longer than setting up the guns themselves. The TRF factor for bombardment rockets and mortars does not include a component for setting up a fire control network, as these weapons more often fired blind or with very limited observer support. Artillery TRF factors include a time component to set up at least a rudimentary fire control network.

***

b. Fire Control Effect (FCE)

The FCE is a direct measure of the ability of the weapon system to newly acquire, track and hit any stationary or moving target. This effect is independent of crew training (their tactical combat proficiency), and is inherent in the technology and design of the individual weapon system.

This factor is very important for Mobile Fighting Machines (MFMs), especially Armoured Fighting Vehicles (AFVs). It is treated in depth in the section on Calculating MFM's Overall Combat Power Coefficients (OCPCs). [186] Because they are more applicable to MFMs, it is in the aforementioned section that the following sub-factors are defined and explained: Turret Crew Efficiency (TCE), Main gun Optics Quality (OPQ), Turret Basket Effect (TBE), Rotating turret present/Turret Drive Reliability (TDR), and Target observation and Indicator Devices (TID).

For non-mobile weapon systems or squads the FCE factor is much less significant, except for <u>direct fire heavy weapons</u>. These include infantry guns, anti-tank and anti-aircraft guns. For these weapons the FCE factor is 0.76, 0.85 or 0.9, depending on the individual weapon. These figures are based on FCE values calculated for MFMs and use values for sub-factors shown in the matrix below.

Fire Control Effect for non-mobile direct fire weapon systems					
FCE	**(TCE)**	**(OPQ)**	**(TBE)**	**(TDR)**	**(TID)**
0.76	1.10	0.7	0	0.8	1
0.85	1.10	0.8	0	0.9	1
0.90	1.10	0.9	0	0.9	1

For all light infantry weapons and all indirect fire weapons, the FCE factor = 1.

***

c. Concealment and Protection Factor (CPF)

The CPF factor is a measure of how difficult the weapon is to conceal and any protection afforded by any additional armoured shields.

The biggest influence on the CPF factor is the dimensions of the weapon system in action. Obviously low silhouette or/and small weapons gain most benefit. Armoured shields such as those found on most AT guns provide some benefit, but this is generally considered to be small.

The range of CPF factors is from 0.5 to 4. Only infantry squads without a lot of heavy equipment get a CPF rating of 4, while huge heavy artillery pieces can go as low as 0.5. Generally a CPF value of 1 or greater means the weapon receives some benefit from its size or/and armour protection. Such weapon systems have a good chance of survival in a direct fire fight with the enemy. Weapon systems with a CPF value below 1 are vulnerable and should be used at long range or kept well back from the front line.

***

d. Defensive Dispersion Factor (DDF)

The DDF factor is a measure of the ability to disperse to avoid enemy fire. It is related to the Typical Target Dispersion Factor (TDi) discussed in relation to calculating a weapon's WCPC.

The DDF factor only applies to squads . For all other weapon systems the DDF factor = 1. The range of DDF factors is from 1 to 5. The DDF factor for any squad is directly proportional to the number of men in the squad, and inversely proportional to the amount of transport (e.g. bicycles, motor cycles, and horses) and heavy equipment in the squad.

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3) Calculating a Land Based, Motorised Mobile Fighting Machine's (MFM's) Overall Combat Power Coefficient (OCPC)

Motorised Mobile Fighting Machines (MFMs) include: tanks, command tanks, flame thrower tanks, assault guns, tank destroyers, all types of self-propelled guns, armoured cars, armoured personnel carriers, all types of reconnaissance and observation vehicles, armoured ammunition carriers, armoured trains, miscellaneous AFVs and transport type vehicles. The latter are usually not armed except for the crew with self-defence small arms, but for this purpose we will consider them as MFMs.

The following factors are considered in calculating all MFM's OCPCs. All vehicle Weapons Combat Power Coefficients (WCPCs) calculated in step 1) above (i.e. as detailed in 'Calculating individual Weapon Combat Power Coefficients (WCPCs)'), Battlefield Mobility Factor (MOF), Range of Action (RA), Protection Factor (PR), Shape and Size Factor (SSF), Open Top Factor (OTF), Rapidity of Fire Effect (RFE), Fire Control Effect (FCE), Ammunition Supply Effect (ASE) and Half Track/Wheeled Effect (WHT). [187]

For MFMs the Overall Combat Power Coefficient (OCPC) is given by,

$$OCPC_{MFM} = \left(\left(\sum_{1}^{MBE} WCPC_{MFM} * MOF * RA \right) + \left(PR * SSF * OTF \right) \right) * RFE * FCE * ASE * WHT$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all LMGs and larger weapons on the Mobile Fighting Machine (MFM), added up using modified Multi Barrel Effect rules (refer below).

The reader should note that the <u>factors WCPC, MOF and RA are essentially offensive components</u> while <u>PR, SSF and OTF are essentially defensive components</u>. Factors RFE, FCE, ASE and WHT enhance both the offensive and defensive power of the vehicle. Hence the overall combat power is the enhanced sum of the offensive and defensive elements.

***

a. MFM Weapons and Multi Barrelled Effect rules

All the individual weapon WCPCs on MFMs are added together using slightly modified Multi Barrelled Effect (MBE) rules. [188] For MFMs the <u>MBE effect does not apply to the first or principal weapon on the MFM.</u> However it applies to all weapons after the first one.

For example, consider the *Panzerkampfwagen* III Ausf F (Sd Kfz 141). This tank has 1x 3.7cm KwK tank gun and 3x MG34 machine guns. The 3.7cm KwK tank gun has a WCPC value of 29 while the AFV mounted MG34s each have a WCPC value of 2.28. The tank's WCPC is then = 29 + 2.28 + (2.28x0.5) + (2.28x0.33) = 33.

When calculating the MFM's WCPC, the primary weapon is always first, followed by the remaining weapons in order of decreasing WCPC values.

Armoured Personnel Carriers (APCs) require special consideration when calculating the overall vehicle WCPC. The weapons value for the APC includes permanently mounted weapons, plus the small arms in the infantry squad typically carried by that APC. [189] If the infantry squad dismounts from the APC then the squad still functions normally as foot infantry with all its small arms. This effectively means giving double value to all squad small arms carried into battle on APCs.

For example, consider the *Mittlere Gepanzerte Mannschaftskraftwagen* (Sd Kfz 251). This APC carries a full German armoured infantry (*Schutzen*) squad: that is a heavy rifle squad with an additional MG34 LMG. In addition the Sd Kfz 251 usually has a permanently mounted MG34 (usually with a swivel mount and a small gun shield). [190] Thus the total Sd Kfz 251

WCPC includes an AFV mounted 7.92mm MG34, an additional MG34 LMG, and all the weapons in a heavy rifle squad. The heavy rifle squad can fire its weapons from inside the APC, or it can operate outside the APC with all its weapons and the additional MG34 LMG. In the latter case the APC (and its dedicated two man crew) gives supporting fire to the heavy rifle squad operating outside the vehicle.

Interestingly enough this is exactly the tactics employed by German panzer grenadiers in APCs operating with tanks. Armoured infantry operating in APCs and supporting tanks is much more effective and less vulnerable than infantry riding on the tanks themselves. This is because in the latter case the infantry has to immediately dismount when the shooting starts, or face annihilation. This means that 'tank riding' infantry immediately revert to foot infantry, in the tactical sense, once the tanks come under even moderate fire. A common perception (unfortunately promoted by many popular war movies) is that it is save to ride into battle on tanks, or stick close to them in battle using the tank for cover. In reality however, tanks usually draw the most intense fire from all sorts of weapons including artillery, mortars, AT guns, AA guns, aircraft and infantry small arms. A single HE shell exploding on the outside, or next to the tank, will not usually affect the tank crew but will wipe out any infantry squad sitting outside on the tank or standing next to it. Most veteran infantry won't even follow a tank into action, unless it's at a reasonable distance or they have some form of armour protection themselves.

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b. Battlefield Mobility Factor (MOF)

The MOF factor is a measure of how mobile the vehicle is around the battlefield. It is often stated that the most successful AFVs are a good balance of mobility, protection and firepower. Hence mobility is a very important factor in determining any MFM's lethality, particularly its ability to change position on the battlefield, or 'battlefield mobility'.

On first analysis, one might believe that the maximum road speed of the vehicle was an appropriate measure of battlefield mobility. However research shows that using this as the basis for the MOF factor presented

severe problems in representing true battlefield mobility. [191] These problems include the following.

i. Some vehicles, particularly fast reconnaissance and transport vehicles (trucks), were designed to be fast under certain conditions. However these same vehicles often had very poor cross-country ability. Many armoured cars and other wheeled vehicles did not perform well crossing even moderate terrain. In effect these vehicles would have an apparently higher MOF factor compared to slower fully or semi-tracked vehicles, while in reality the opposite was the case in many tactical situations. This leads to unrealistic results, and alone severely weakens the case for basing MOF on maximum speed.

ii. A vehicle's top speed bears little relationship with its ability to negotiate obstacles, inclines, ditches or rivers. Technical information on WWII tanks often present a lot of information on their ability to negotiate obstacles, the maximum inclines they can ascend, the depth of water they can ford, etc. All these combat enhancing features are ignored if only using top speed.

iii. A lot of technical information on WWII MFMs present a vehicle's top speed, but do not differentiate between top road speed and top cross-country speed. We are really interested in cross-country speed because battles in WWII were rarely fought from roads and the large majority of tactical situations involve moving cross-country.

iv. When information is provided for cross-country speed there is almost no information on what type of terrain constitutes 'cross-country'. It could be anything from a firm, flat, empty field to a marsh filled with thick forest and streams. For that matter there is also no information on what constitutes a 'road', and the average roads in Europe were very different to the average roads in the western USSR during WWII.

v. Some vehicles had the ability to travel on wheels or tracks. The most well-known example in Operation Barbarossa is the BT series of Soviet tanks. These tanks could move rapidly in wheel mode on roads but had normal speeds on tracks, which were almost always used in combat or when operating close to the front lines. If simply top speed

is used (using its wheels), these types of vehicle would gain an unrealistic boost to their OCPC values. [192]

So what parameters better represent a MFM's true battlefield mobility than simply top speed? After analyses, the most consistent and realistic results were obtained using the maximum horse power of the engine under normal operation, divided by the combat weight. In almost all cases the MFM's power to weight ratio was directly proportional to the vehicle's top road speed and top cross-country speed, as well as the ability of the vehicle to negotiate obstacles and ascend inclines.

Once the MFM's horse power/combat weight ratio (in hp/metric ton) has been established, the MOF factor is determined by using,

$$MOF_{MFM} = \sqrt{power / combat\ weight_{MFM}} * 0.35$$

It is important to use the weight in combat to calculate MOF, because there is often considerable variation between empty and loaded vehicles. Some AFVs carry more fuel and ammunition, as a proportion of their empty weight, than others. Such vehicles enjoy the benefits of longer range (Range of Action (RA)) and more ammunition (Ammunition Supply Effect (ASE)) which are considered below. They must therefore pay the price in lower MOF factors to produce more realistic OCPC values.

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c. Range of Action (RA)

The combat potential of any MFM is affected by its operational range, which is the distance it can travel without refuelling. This Range of Action (RA) is essentially part of the overall battlefield mobility of the MFM.

The two options available in determining the RA factor for MFMs are to use range on roads or cross-country. On balance using the range on roads seemed to produce more realistic and consistent results for several reasons.

i. The variation in RA factors, calculated for fully or semi-tracked vehicles using road range versus cross-country range, was small. Thus for tracked vehicles there was little or no additional realism in using cross-country range to calculate RA, as opposed to the road range.

ii. The information on AFV's cross-country range varied widely depending on sources used. The same sources produced more consistent information when using road range.

iii. There is almost no information on what type of terrain constitutes cross-country. Also what constitutes a road seems to have less variation.

iv. Many wheeled MFM types have no cross-country range given. This is probably because they couldn't move cross-country without considerable difficulty.

Once the MFM range on roads (in kilometres) has been established, the RA factor is determined using,

$$RA_{MFM} = \sqrt{road\,range_{MFM}} * 0.08$$

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d. Protection Factor (PR)

The PR factor is a direct measure of the armour protection on the MFM. The slope and shape of the armour is <u>not</u> included as part of the PR factor: this is included in the Shape and Size Factor (SSF) considered in the next entry. The MFMs benefiting from high PR factors are usually termed AFVs (Armoured Fighting Vehicles).

To measure PR it is simple and possible to use the weight of the vehicle, as it is reasonable to assume that weight is proportional to the level of armour protection. [193] However this takes no account of the size of the AFV or the distribution of armour, which can lead to very strange and unrealistic results. For example, the *Panzerkamfwagen* II Ausf J weighed 18 tons, but it was a tiny tank with only three crew. The actual armour was 80mm on all

front surfaces and 50mm on all side and rear surfaces, considerably more heavily armoured than the much larger 25 ton *Panzerkampfwagen* IV Ausf H, which was a main battle tank. [194] However, based on weight only, the Pz IVH would have a considerably higher PR factor.

To obtain the most realistic PR factor we will use armour thickness on the seven principal surfaces of the AFV. These surfaces are:

- Superstructure Front (SF) (below the turret ring on tanks; sometimes called the driver's plate or glacis plate).
- Superstructure Side (SS) (below the turret ring on tanks).
- Superstructure Rear (SR) (below the turret ring on tanks).
- Turret Front (TF) (includes the gun mantlet, same as superstructure front on turretless AFVs).
- Turret Side (TS) (same as superstructure side on turretless AFVs).
- Turret Rear (TS) (same as superstructure rear on turretless AFVs).
- Average Top (AT) (average of superstructure and turret roof).

AFV structure in WWII can usually be broken down to the hull, superstructure and main turret. The hull of the vehicle is essentially the armoured floor and sides containing the wheel axels, suspension, transmission and engine structure. This is usually the least well armoured part of the AFV (excluding the roof) and has vertical sides. However the exposed hull is usually low down and often protected by wheels and parts of the superstructure. The superstructure and turret form the most important armoured elements of the AFV. These contain the thickest and most steeply sloped armour on the AFV as the vast majority of hits from all weapon types (except AT mines) are on these surfaces. For our purposes we will consider only armour on the superstructure and turret of the AFV. [195]

On AFVs with no rotating turret, such as turretless assault guns, the fighting compartment is considered the 'turret'. In these cases the superstructure armour extending over the fighting compartment is considered to be the AFV's 'turret' armour. In addition, on some rare AFVs

the hull armour on the front and rear extends upwards to a large degree, blurring the distinction between hull and superstructure. In these cases the armour most exposed to hits is used.

The key question now remains: what weighting do we give each surface to determine the overall protection offered by the armour?

The single biggest cause of incorrect and unrealistic AFV armour values being used, in military simulations, is the assumption that the tank's frontal armour is by far the single most dominant factor in its protection. The more sophisticated tactical-level simulations do use armour facing rules. However the majority of tactical/operational simulations use one value for an AFV's armour. This is usually based on the frontal armour thickness and degree of slope, leading to 'theoretical' AFVs with much heavier protection than the historical AFVs that are meant to be represented. This practice totally ignores the fact that throughout WWII (and even today) tank designers felt it necessary to provide all round protection. The Soviets in particular never skimped on ensuring all-round protection for their tanks. They correctly concluded that AFVs without all-round protection could not survive long enough in assault conditions to fulfil their primary functions.

The main reason for this 'preoccupation with frontal armour' is the idea that the main purpose of any WWII tank was to engage enemy AFVs head on. The assumption is that most tanks were lost in this type of combat and this was how they spent most of their time in action. During WWII the reality was the exact opposite. Tanks spent by far the majority of their time fighting non-armoured and non-mobile weapons with high explosive rounds. When they did engage enemy armour, it was often not head on. In addition the majority of tanks were not lost to enemy tank or tank-destroyer gun fire. The majority were lost to AT guns, artillery, mines, close assaulting infantry, infantry AT weapons, air-attack or simply abandoned/blown up as operational losses. All these causes of loss, except the last, demand all-round protection because the majority of hits from these types of attack were probably non-frontal hits.

One of the most famous and leading panzer aces of WWII stated "to destroy an enemy tank is important but to destroy an anti-tank gun is doubly

so”. [196] During WWII almost all tankers feared the concealed AT weapon more than enemy armour (and this state of affairs hasn’t changed much on today’s battlefield). The purpose of the AT gun (or AT infantry squad) is to be carefully concealed and then pick off AFVs before they can get a lock or use artillery. In other words the AT gun will almost always get the first few shots, and if they know what they are doing the gun is concealed on approaches so the tank has to show some side angle. As the primary function of the tank is to break through and exploit such defences (not to destroy enemy tanks as such), and as there are many more AT guns around than tanks, then the tank’s ability to survive heavy dug in AT defences is a much truer measure of its protection than its ability to engage enemy armour. Surviving this type of action requires good overall armour protection. In addition aircraft rarely hit the front of a tank. During WWII they invariably dropped a bomb on it, used heavy rockets, or pumped cannon shells through the top. Thick and well sloped frontal armour provides no significant benefit against this type of attack. Similar arguments can be made for plunging artillery fire, AT mines and close infantry assaults. The irony is that tanks with thick frontal armour are in fact more vulnerable to all these types of attack because they usually have thinner armour everywhere else in order to keep the overall weight down.

A good historical example of the importance of all round protection is the experience of the Panther tank on the Western Front during 1944-45. This is a particularly suitable example because the Panther tank had excellent frontal protection but mediocre protection on its other surfaces. The frontal protection on the Panther was even superior to that on the heavier Tiger I tank (due to its slope from the vertical and curved gun mantlet), which has prompted several military simulations to give the Panther a superior all-round armour protection value, and some authors to state that, one for one, the Panther was a superior tank. [197]

In 1944/45 the British Army’s Office of Research and Analysis commissioned three studies of captured and/or destroyed Panther tanks to analyse causes of loss. These were an examination of 80 Panthers captured between 6th June and 7th August 1944, 96 Panthers captured from 8th to 31st August 1944, and 47 Panthers captured from 17th December 1944 to 16th January 1945. [198] Of the 223 tanks examined, 63 (28%) were

destroyed by AP rounds, 8 (4%) by hollow charge (from bazooka or PIAT infantry weapons), 11 (5%) by HE rounds from artillery, 14 (6%) by aircraft (all weapons), 103 (46%) abandoned or blown up their crews, and 24 (11%) from unknown causes. This means that at most only 28% of the tanks were lost due to direct combat with enemy tanks, tank-destroyers or AT guns. Of these, it is reasonable to assume at least 30% (19 tanks) were lost due to penetrations from AT guns. Therefore, at most 20% of total losses were as a result of direct fire from Allied AFVs, and probably a very large proportion of these were side penetrations. At least 23% of total losses were from probable penetrations of side, rear and top armour (from bazooka or PIAT infantry weapons, artillery, AT guns, aircraft rockets and aircraft cannon), and around 57% of total losses were from other causes which had nothing to do with frontal armour at all. In other words what matters most is the tank's all-round survivability and not simply how thick or slopped its frontal armour is.

There are also several other telling statistics which emerge from the British Army's Office of Research and Analysis' reports. The first is shown below and clearly indicates the Tiger I was a significantly tougher all-round tank than the Panther. [199]

Average Number of Hits to Knock out Each Type of Tank (Western Europe, 1944-45)

Tank Type	Average number of hits to knock out the tank	Average number of penetrations to knock out the tank
Panzer VI (Tiger I)	4.2	2.6
Panzer V (Panther)	2.55	1.9
Panzer IV	1.2	1.2
Sherman M-4	1.63	1.55

The average Panther took only 61% of the AP hits that the average Tiger took before it was knocked out. In addition the Tiger was significantly stronger than any other tank at surviving a penetrating hit: in this case the average Panther took only 73% of the penetrative hits that the average Tiger took before it was knocked out. Note, the kinetic energy left in a round after a penetrative hit is inversely proportional to the thickness of armour it penetrates. In other words, the thicker the armour, the less energy a round has left over after a penetration and the less damage it will do to the tank internally. As the Panther had superior frontal protection, the only realistic

explanation for all the above figures is that a much higher proportion of the hits were on non-frontal surfaces than is commonly perceived: on these surfaces the Tiger I had much thicker armour as well as superior overall protection.

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The second important report to emerge from the same series (of reports) goes even further to demonstrate the importance of all round armour protection. A summary of this report is given below: [200]

Distribution of AP Penetrations and AP Failures on German Panzer V (Panther)						
Weapon	Superstructure Front	Turret Front & Gun Mantlet	Turret Side	Superstructure and Hull Side	Turret rear	Superstructure and Hull Rear
Successful Penetrations						
17 Pounder		1	4	9	1	3
3 inch M-10			1	5		1
75mm			1	4		
6 Pounder APDS*		1	1	3		1
6 Pounder APCBC^	1		3	2		
Total	1	2	10	23	1	5
Failed Penetrations						
17 Pounder	2		1			
3 inch M-10	1	1	1			
75mm	1		1	1		
6 Pounder APDS*	3	1				
6 Pounder APCBC^			1			
Total	7	2	4	1	0	0
Total Hits	**8**	**4**	**14**	**24**	**1**	**5**
Penetration/hits	13%	50%	71%	96%	100%	100%
* Special Armour Piercing Discarding Sabot Ammunition (with solid tungsten core, late war)						
^ Armour Piercing Capped Ballistic Capped Ammunition (standard late war AP ammunition)						

The first and most obvious fact from the above data is that no less than 79% of the total hits were on non-frontal surfaces. In other words the Panther's much vaunted frontal armour and slope did not help at all against the large majority of armour piercing (AP) hits from enemy AFVs and AT guns. By far the largest number of hits was on the side (68%). Note, as we have seen above, the proportion of hits from other weapons (such as infantry HEAT weapons, artillery, AT guns, aircraft rockets and aircraft cannon) on the side and rear was likely considerably higher than even this. As we would expect, the data also demonstrates that the Panther's frontal

surfaces were well protected, even against the formidable 17 pounder and 6 pounder firing APDS ammunition. However, the sides of the turret (which received 25% of the total hits) were relatively easily penetrated, and the superstructure and hull sides (which received 43% of the total hits) were easily penetrated by even the weakest Allied AT and tank guns. If even the relatively weakly armed 75mm M4 Sherman or Cromwell could outflank the Panther, it could quickly get a killing shot.

The same tank would have to penetrate 80mm of armour on a Tiger I in the same position, which means it would need to get perilously close as well as achieve a good angle hit (i.e. as close to 90 degrees as possible). At the same time, hidden AT guns facing a Tiger I side on, especially at 1-70 degrees of angle, are going to have a much harder time than if facing a Panther in the same position. This is confirmed by the Tiger I consistently achieving a higher kill/loss ratio during WWII compared to the Panther. This was especially apparent against AT guns, artillery and other weapons. Tiger tanks (including Tiger IIs) destroyed at least 10300 enemy tanks and, equally as important, a staggering 11380 AT guns and artillery pieces during WWII. This was achieved for the loss of 1725 Tigers (including a large number of operational and strategic losses, i.e. abandoned, broken down, etc). [201] When destroyed AFVs, AT guns, artillery, infantry, and other weapons and equipment are included, the Tiger I tank almost certainly achieved the highest kill/loss ratio of any tank in history. [202] There is no doubt that the Tiger tank's success was largely due to its all-round protection .

On balance, any equation attempting to calculate a realistic single armour protection figure for AFVs in WWII, should give the following approximate weighting to the various surfaces: 45% front (turret front and superstructure front), 35% for both sides (17.5% to each turret side and superstructure side), 10% rear (turret rear and superstructure rear) and 10% top (turret top and superstructure top). This will ensure a reasonably realistic figure for 'overall armour protection' against the multitude of anti-tank weapons fielded against AFVs during WWII.

Once the average armour thickness (in mm) has been established on the various AFV surfaces, the PR factor is therefore determined by,

$$PR_{MFM} = ((0.2 * SF) + (0.2 * SS) + (0.05 * SR) + (0.25 * TF) + (0.15 * TS) + (0.05 * TR) + (0.1 * AT)) * 3.5$$

where SF is the Superstructure Front armour thickness in mm, SS is the Superstructure Side, SR is the Superstructure Rear, TF is the Turret Front, TS is the Turret Side, TR is the Turret Rear and AT is the Average Top (superstructure and turret roof).

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e. Shape and Size Factor (SSF)

The SSF factor is a factor representing the increase or decrease in protection as a result of the shape and size of the MFM. It includes the added protection due to armour slope on the seven principal surfaces as detailed in the PR factor above, the overall size and height of the vehicle, and a factor for any severe ‘shot traps’.

i. SSF Modifications due to Sloped Armour

If the single biggest cause of incorrect and unrealistic AFV armour values is the assumption that the tank’s frontal armour is by far the most dominant factor in its protection, then the second biggest cause is making the same simple assumption about frontal sloped armour. Exactly the same arguments as detailed for the PR factor apply: the AFV’s all-round protection must be considered and not ignored.

Detailed calculations of armour penetration vs slope involve quite complex differential equations, and even today the mathematics is somewhat debated over. Variables include: the type and design of ammunition (including materials used), the diameter and mass of the incoming round (e.g. 20mm or 120mm rounds behave differently, even with identical impact velocities, incident angles and armour), and the armour itself (e.g. face hardened armour will tend to improve deflection because the incoming round has less opportunity to groove into the armour plate and hence effectively increase the incident angle (of impact)). For World War II era weapons and armour,
Graph Pen vs Slope shows the most typical armour penetration reduction vs. angle of armour from vertical. [203]

The equations leading to this graph make some key assumptions which are detailed below. These assumptions are not unreasonable when looking for a 'standard' to assess the apparent increases in armour protection due to slope, for the stated reasons.

i. **The data is for standard APCBC (Armour Piercing Capped Ballistic Capped) ammunition** .

   APC (Armour Piercing Capped) ammunition consists of a hard steel cap fitted to armour piercing projectiles to assist penetration of face-hardened armour. By early-mid WWII APC was common as simple solid steel AP shot had a tendency to shatter when hitting face hardened armour. [204] To reduce air resistance in flight a long and pointed cap was fitted over the hard steel cap. The so called 'ballistic cap' would collapse upon impact enabling the 'armour piercing cap' to do its work. With both armour piercing and ballistic caps fitted, these rounds were known as APCBC (Armour Piercing Capped Ballistic Capped). APCBC was very common by mid WWII and was the standard round by the end of WWII. [205]

   Using APCBC ammunition as the standard also largely negates (but not totally) the effect of face hardened armour in our MFM OCPC calculations. This is a process by which the armour surface is heat treated to make its outer surface harder and more resistant to penetration. German tanks employed face hardened armour early in WWII in their medium tanks, largely reducing the effect of Allied AP shot at that time. The Soviet's use of face hardened armour is uncertain but is unlikely to be present on pre-1941 AFV production. The use of face hardened armour is not factored into our OCPC calculations so most of the Soviet AFVs present in 1941 gain this additional but unrealistic benefit in their OCPC values.

ii. **The armour is considered to be homogeneous** .

   Homogeneous armour was the most common type used in WWII AFVs.

iii. **The round is assumed to be travelling in a flat horizontal direction (90 degrees from vertical) upon impact** .

Most armour piercing ammunition was fired from relatively high velocity guns with a low time of flight. These weapons had a flat horizontal trajectory and the error introduced by the slight downward angle of flight, is negligible. [206]

iv. **The round is between 75mm and 128mm calibre** .

The assumption that the average APCBC round is 75mm to 128mm, is probably the most contentious assumption. The differential equations for armour penetration versus slope show that:

- The reduction in penetration due to slope increases progressively with progressively smaller calibre rounds.
- With smaller calibre rounds, the reduction in penetration is largest with angles of incidence beyond around 35 degrees.
- Importantly; the degree of reduction in penetration gets progressively smaller as the calibre increases. Therefore, at the same angle, the difference in penetration between a 75mm and 128mm round is much smaller than the difference between a 75mm and 37mm round. For example, using APCBC ammunition against homogeneous armour sloped 50 degrees from vertical, the 128mm round penetration is reduced by 0.55, the 75mm round penetration is reduced by 0.51, the 50mm round is reduced by 0.475 and the 37mm round is reduced by 0.415.

  In other words the apparent increase in protection due to the 50 degree slope is 1.82, 1.96, 2.11 and 2.41 using 128mm, 75mm, 50mm and 37mm rounds, respectively. Thus the difference (in apparent increase in protection) between the 128mm and 75mm round is only 0.14, while the difference between the 75mm and 37mm round is 0.45 (3.2 times greater).

  An even more informative way to look at this data is: the difference between the 128mm and 75mm round, measured in

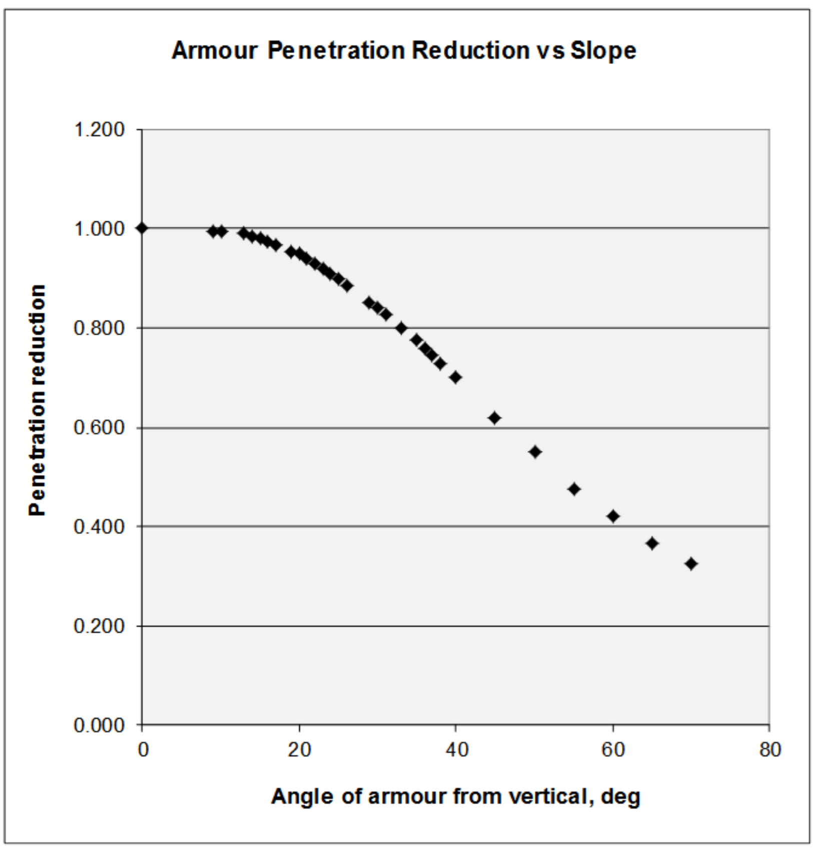
terms of the ‘difference in apparent increase in protection’ over ‘the difference in calibre’, is 8.7 times less than the equivalent difference between the 50mm and 37mm round. [207]

When looking for a ‘standard’ to assess the apparent increases in armour protection due to slope for WWII AFVs, the calibre range 75-128mm is appropriate for three main reasons. Firstly, by 1941 75mm plus calibre AFV and AT guns were becoming common. Secondly, the 75-90mm calibre became the most effective standard issue AT guns for most combatants during WWII. Thirdly, as demonstrated above, the differences (in penetration due to slope) in larger calibre weapons are much less than the same differences in smaller calibre weapons.

Graph Pen vs Slope

Typical Armour Penetration Reduction vs. Slope from Vertical

Angle of Armour fr Vert deg (x)	Penet-ration Reduction (y)	Apparent Armour increase
0	1.000	1.00
9	0.996	1.00
10	0.995	1.01
13	0.990	1.01
14	0.986	1.01
15	0.980	1.02
16	0.974	1.03
17	0.968	1.03
19	0.955	1.05
20	0.950	1.05
21	0.940	1.06
22	0.930	1.08
23	0.920	1.09
24	0.910	1.10
25	0.900	1.11
26	0.886	1.13
29	0.850	1.18
30	0.840	1.19
31	0.827	1.21
33	0.801	1.25
35	0.775	1.29
36	0.760	1.32
37	0.745	1.34
38	0.730	1.37
40	0.700	1.43
45	0.620	1.61
50	0.550	1.82
55	0.475	2.11
60	0.420	2.38
65	0.365	2.74
70	0.325	3.08



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Once the average armour slope (in degrees from vertical) has been established on the various AFV surfaces, the SSF factor due to sloped armour only is determined using,

$$SSF_{MFM\ ArmSlope} = ((0.2 * SF) + (0.2 * SS) + (0.05 * SR) + (0.25 * TF) + (0.15 * TS) + (0.05 * TR) + (0.1 * AT))$$

where SF is the superstructure front <u>apparent increase in protection due to the determined degree of slope</u>, SS is the superstructure side apparent increase, SR is the superstructure rear apparent increase, TF is the turret front apparent increase, TS is the turret side apparent increase, TR is turret rear apparent increase, and AT is the average superstructure and turret roof apparent increase.

There are two approximations used for vehicles with cylindrical shaped turrets and curved gun mantlets:

- AFVs with cylindrically shaped (or circular) turrets, such as the BA-20 Armoured car and tanks such as the T-28, T-35 and BT series, get an ‘apparent increase in protection’ value of 1.06 for the relevant turret surfaces. This is equivalent to the extra protection provided by a surface sloped at 21degees from the vertical, which is a modest increase. Although the armour on these vehicles is not sloped in the vertical plane, it is effectively sloped in the horizontal plane. Thus, if an incoming round does not strike the turret side at exactly 90 degrees to the surface’s tangent plane, then it will experience the effects of sloped armour, i.e. an increased tendency to deflect. In this case the tendency is to deflect away in the horizontal direction instead of in the vertical direction.

- AFVs with an obvious curved gun mantlet on the turret front, such as on T-60, T-26, KV-1 and Panther tanks, get an ‘apparent increase in protection’ value of 1.10 for the turret front surface. This is equivalent to the extra protection provided by a surface sloped at 24 degrees from the vertical. Again, if an incoming round does not strike the turret mantlet at exactly 90 degrees to the surface’s tangent plane, then it will experience the effects of sloped armour, i.e. an increased tendency to

deflect. In this case the tendency is to deflect away in the vertical direction, either upwards or downwards. Note, a downward deflection from a curved gun mantlet was not necessarily a good thing because this quite often led to penetration of the much thinner superstructure top, below the gun mantlet (refer below for more on potential 'shot traps').

ii. SSF Modifications due to Size, Height and Shot Traps

We must now consider the other parameters relating to an MFM's SSF factor, which are the overall size and height of the vehicle, and any severe 'shot traps'.

Obviously the overall size of the vehicle impacts its battlefield survivability, particularly AFVs which often come under direct fire. The whole idea behind light tanks and reconnaissance vehicles is that they gain significant protection from being smaller and more mobile than main battle tanks. A smaller size enhances concealment and reduces target cross section. Once the length, width and height of the vehicle have been determined, the overall SSF factor is increased or decreased in the range +10% to -5% using the following basis:

- Volume occupied by the vehicle < 35 cubic metres, then SSF is multiplied by 1.1.
- Volume occupied by the vehicle > 35 and =< 65 cubic metres, then SSF is multiplied by 1.05.
- Volume occupied by the vehicle > 65 and =< 95 cubic metres, then SSF is multiplied by 1.00.
- Volume occupied by the vehicle > 95 cubic metres, then SSF is multiplied by 0.95.

***

Of the three dimensions, by far the most important in terms of battlefield survivability is height. This is because a low height produces a low silhouette. In most terrain a low silhouette reduces the parts of the

vehicle exposed to enemy fire, enhances concealment, makes it easier for the vehicle to take advantage of hull down or entrenched positions, and makes it easier for the vehicle to take advantage of any rolling terrain. Turretless AFVs such as StuG assault guns get the benefit of having no turret by being smaller with a considerably lower silhouette. [208] Note, however, that these same vehicles can pay a severe price in terms of their Fire Control Effect (FCE) values, and they usually have a reduced Ammunition Supply Effect (ASE) value. Refer entries below for details on these parameters.

Once the height of the vehicle has been determined, the overall SSF factor is increased or decreased in the range +10% to -5% using the following basis:

- Height of the vehicle < 2.2 metres, then SSF is multiplied by 1.1.
- Height of the vehicle > 2.2 and =< 2.5 metres, then SSF is multiplied by 1.05.
- Height of the vehicle > 2.5 and =< 3 metres, then SSF is multiplied by 1.00.
- Height of the vehicle > 3 metres, then SSF is multiplied by 0.95.

***

The last parameter to be considered in determining the overall SSF factor for an MFM is 'shot traps'. By and large, shot traps are ignored in most literature discussing the combat power of WWII fighting vehicles. Shot traps are the result of armour shape which causes an incoming round to be deflected onto weaker armoured areas, or cause the shot to be 'trapped' so it cannot easily rebound. The latter type of trap ensures that most of the kinetic energy of the round is channelled into destroying the AFV.

For calculating MFM SSF factors, shot traps are defined separately for non-armoured vehicles and AFVs. Non-armoured vehicles which are not designed to come under direct fire have many irregular surfaces which can

be called shot traps. For these vehicles the overall SSF factor is automatically decreased by 5% (multiplied by 0.95).

On AFVs, in order for the armour shape to qualify as a shot trap, two criteria need to be met.

i. Firstly, the shot trap must be present on the vehicle's front so a round hitting the vehicle front will possibly get caught in the shot trap. Shot traps on the vehicle sides, particularly at the join between superstructure and lower hull and around the wheels, are ignored.

ii. Secondly, the round must have a reasonable likelihood of being deflected onto weaker armour or a structurally weaker part of the vehicle, which must in turn be protecting the vehicle's crew. Shot traps causing rounds to deflect onto stronger armour, structurally stronger parts of the vehicle, exterior fittings, wheels and tracks, do not qualify as shot traps for this purpose.

In WWII AFVs the two most common causes of lethal shot traps are an overhanging turret and a sharply curved turret front or gun mantlet. On some AFVs the turret overhangs the walls of the sloped superstructure front and/or sides. Any high velocity round ricocheting upwards off the sloped superstructure, as its meant to do, will probably get caught under the turret and quite possibly penetrate or rip the turret off completely. [209] Other AFVs have sharply curved turret front and/or gun mantlets which cover most of the turret front. The emphasis here is 'sharply curving' as many AFVs had curved turret fronts. Depending on the specific design, any rounds impacting just below the level of the barrel are deflected downwards through the superstructure roof or into the turret ring. [210]

Once it has been determined that an AFV has a qualifying shot trap, the overall SSF factor is decreased in the range -5% to -10% depending on the severity, using the following basis:

- Overhanging rotating turret, then SSF is multiplied by 0.95.
- Overhanging fixed gun structures on turretless AFV, then SSF is multiplied by 0.9.

- Sharply curved turret front with high probability of lethal deflection, then SSF is multiplied by 0.95.
- Overhanging rotating turret <u>and</u> sharply curved turret front as above, then SSF is multiplied by 0.9.
- Multiple protruding rotating or fixed turrets (usually older multi turreted AFVs), then SSF is multiplied by 0.95.

In general, AFVs with heavily sloped armour are more likely to receive a shot trap penalty. This is because these AFVs receive a major boost to their SSF factor and resultant OCPC values due to the fact that they are using enhanced deflection as a defensive tool. If these same deflections result in penetrations of other parts of the AFV, then the original protection offered by the sloped armour is significantly reduced. On the other hand, flat sided AFVs receive little or no benefit due to sloped armour. The surfaces of these AFVs are already considered to be a lesser form of shot trap, and they derive their strength from being able to stop the round regardless of deflections.

***

Once all the parameters relating to armour slope, size, height and shot traps have been determined, the overall MFM SSF factor is given by:

$$SSF_{MFM} = SSF_{MFM\ Arm\ Slope} * SSF_{MFM\ Size} * SSF_{MFM\ Height} * SSF_{MFM\ Shot\ Traps}$$

where: $SSF_{MFM\ Arm\ Slope}$ is the SSF factor due to sloped armour only.

$SSF_{MFM\ Sise}$ is the change in overall SSF factor due to size, in the range +10% to -5%.

$SSF_{MFM\ Height}$ is the change in overall SSF factor due to height, in the range +10% to -5%.

$SSF_{Shot\ Traps}$ is the change in overall SSF factor due to shot traps, in the range -5% to -10%.

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The reader should bear in mind that there are a few disadvantages to heavily sloped armour which are not commonly understood. These are the reasons why tank designers in WWII needed to compromise and did not promptly design a totally ‘flat tank’ for maximum protection. These disadvantages include the following.

i. Reduced internal volume. Obviously the angle of slope from the vertical is proportional to the reduction in internal volume. This disadvantage is the most obvious and possibly the most serious. Reduction in internal volume can mean reduced overall crew including the critical turret crew, reduced ammunition stowage, reduced fuel, reduced engine size/power, reduced internal equipment, reduced numbers of vision/observation devices and reduced main gun depression. Obviously the severity of reduction of these factors depends on the overall design. The early T-34/76 for example had a superb sloped shape, but there was barely enough room in the turret for two men and the crew had few vision devices. The ill effect this had on fire control and tactical handling was dramatic and severely impacted the T-34/76’s overall combat power.

ii. By contrast the Panther tank also employed well sloped armour, but it was a much larger and higher tank, to enable a full crew and all the equipment a German panzer crew would expect. In fact it was longer and higher than the Tiger I. However, despite being large and relatively high, the Panther still paid a price for its sloped armour with reduced internal volume. For example, the Panther carried 79 rounds of 75mm ammunition while the Tiger I carries 92 rounds of the considerably larger 88mm ammunition. [211] Another good example of reduced internal volume is the IS-2 and the later (well sloped) IS-3, which carried only 28 rounds of 122mm ammunition. As these tanks were optimised for destroying emplaced defences and not enemy AFVs, most IS-2s normally carried only 8 to 12 rounds of AP ammunition. The reader should note that ammunition stowage on a tank is vital because if a tank runs out of ammunition in a running battle, it instantly becomes relatively ineffective and nothing more than a target

for the enemy: it generally has to retreat immediately (if it can) or be destroyed.

iii. Reduced turret ring. The turret ring size (in a tank) has the largest influence on the maximum size of gun the tank can carry without producing turret overhang on the superstructure and the resultant shot traps. The turret must have sufficient room for gun recoil movement and, hopefully, efficient servicing of the gun. Obviously the more sloped the superstructure armour is, the smaller the diameter of turret ring available. It is worth noting that the turret ring on the Pz III was similar to the T-34, yet the largest high velocity gun the Germans put on the Pz III was 50mm while the Soviets eventually placed an 85mm gun on the T-34. The T-34/85 however, had severe turret overhang and the complete removal of the turret in action was quite common.

iv. Reduced internal height available for a turret basket. As discussed in the Fire Control Effect (FCE) entry below, a turret basket means the floor of the turret rotates with the gun, which assists the turret crew in several ways. This is a relatively subtle and usually ignored feature in WWII tank design. Well sloped tanks have less height so unless the tank is quite large there is usually insufficient internal height to have a turret basket below the turret. The Germans first used turret baskets in the Panzerkamfwagen III Ausf H, and this was subsequently retro fitted to the Ausf E, F and G. [212] All German tanks subsequently had turret baskets, with the well sloped Panther and Tiger II being quite large and high. In WWII the only Soviet tanks fitted with turret baskets were the large pre-war T-28 and T-35 tanks.

v. Reduced number of escape hatches. This is another relatively subtle and almost totally ignored feature in WWII tank design (unless you're a tanker!) . The number of escape hatches is assumed to not influence the SSF factor for our purposes. Its impact is more long term, i.e. operational, in that fewer crewmen survive. It is possible that lack of escape hatches influenced the willingness of a crew to remain in a hit tank and therefore had some influence tactically. Well sloped superstructure and turret armour means there is much less room on the various roofs for escape hatches. In addition putting hatches on the

sloped armour itself severely weakens the armour, and is simply not practical if the hatch itself is too thick. [213]

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During WWII the Soviets were the guiltiest of not providing tank crews with much chance of surviving a penetrating hit leading to fire. Excluding floor hatches, most T-34/76s had only two ways out and two hatches: the turret top with one hatch (or two smaller ones in the T-34/85 and T-34/76 Model 1943) and the driver's front plate where he has to lift a heavy 45mm thick armoured hatch. [214] The IS-2, considered by many as an outstanding WWII design, had only one way out and two hatches. Anyone who couldn't make it to the turret top, after waiting for his colleagues in the turret to evacuate, was basically cooked. It is unlikely that American or British tankers would have accepted this design. The Pershing and Sherman both had three ways out and four hatches.

The German Panzer III had four ways out and three escape hatches (as well as two small hatches above the transmission forward, one of which enables access to the driver's position). [215] The Panther had four ways out and four hatches, while the Tiger I had four ways out and five hatches (both tanks had turret rear ammunition loading and escape hatches). The Panzer IV was the easiest to get out with five ways out and five escape hatches. Fewer escape hatches is generally one of the penalties for smaller size and well slopped armour. However it is significant that the Germans ensured sufficient roof room for escape hatches in the Panther and Tiger II despite well sloped armour. These tanks were naturally larger and higher than their Soviet counterparts. Anyone who has studied statistics on the number of tank crew who perished in tank fires, the speed a tank burns when hit and its fuel or ammunition propellant catches fire, and the effect a high velocity impact has on distorting and jamming one or more escape hatches, will know this is not a trivial or small issue in a tank's design. Ask any tanker.

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f. Open Top Factor (OTF)

The OTF factor is a factor representing the decrease in overall protection as a result of not having all round armour, or even all-round structural protection. The OTF value range is 0.4 to 1, depending on the degree of reduction.

- Vehicles with fully enclosed armour automatically have an OTF factor of 1.
- Vehicles with fully enclosed armour, except they have an open top turret, have an OTF factor in the region 0.9-0.95 (depending on the specific design).
- Armoured Personnel Carriers (APCs) and self-propelled weapons with all round armour, but much larger 'missing roof area' than on a turret, have an OTF factor in the region 0.8-0.9 (depending on the specific design).
- Self-propelled weapons with armour only at the front and sides have an OTF factor in the region 0.6-0.8 (depending on the specific design).
- Self-propelled weapons with only a gun shield have an OTF factor in the region 0.45-0.6 (depending on the specific design).
- Vehicles with no added protection have an OTF factor in the region 0.4-0.45 depending on the vehicle's structure. In these cases the crew would only have the vehicle's structure to protect them.

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g. Rapidity of Fire Effect (RFE)

We now come to the first of four factors which enhance the offensive and defensive power of the vehicle. Obviously the speed with which the principal weapon on a MFM can be fired and reloaded has a significant bearing on its survival in combat. This is particularly true against enemy tanks and AT guns, and applies both in defence and attack.

The Rate of Fire (RF) factor has already been considered for the principal weapon on the MFM when calculating the weapon's WCPC. Graph RFE shows the relationship between Rates of Fire (RF) versus the

Rapidity of Fire Effect (RFE), expressed as a percentage.[216] As can be seen from the data in Graph RF , weapons with calibre below 45mm have an RFE factor of 1 (100%) while progressively larger calibre weapons up to 600mm have an RFE factor of 0.4 (40%).

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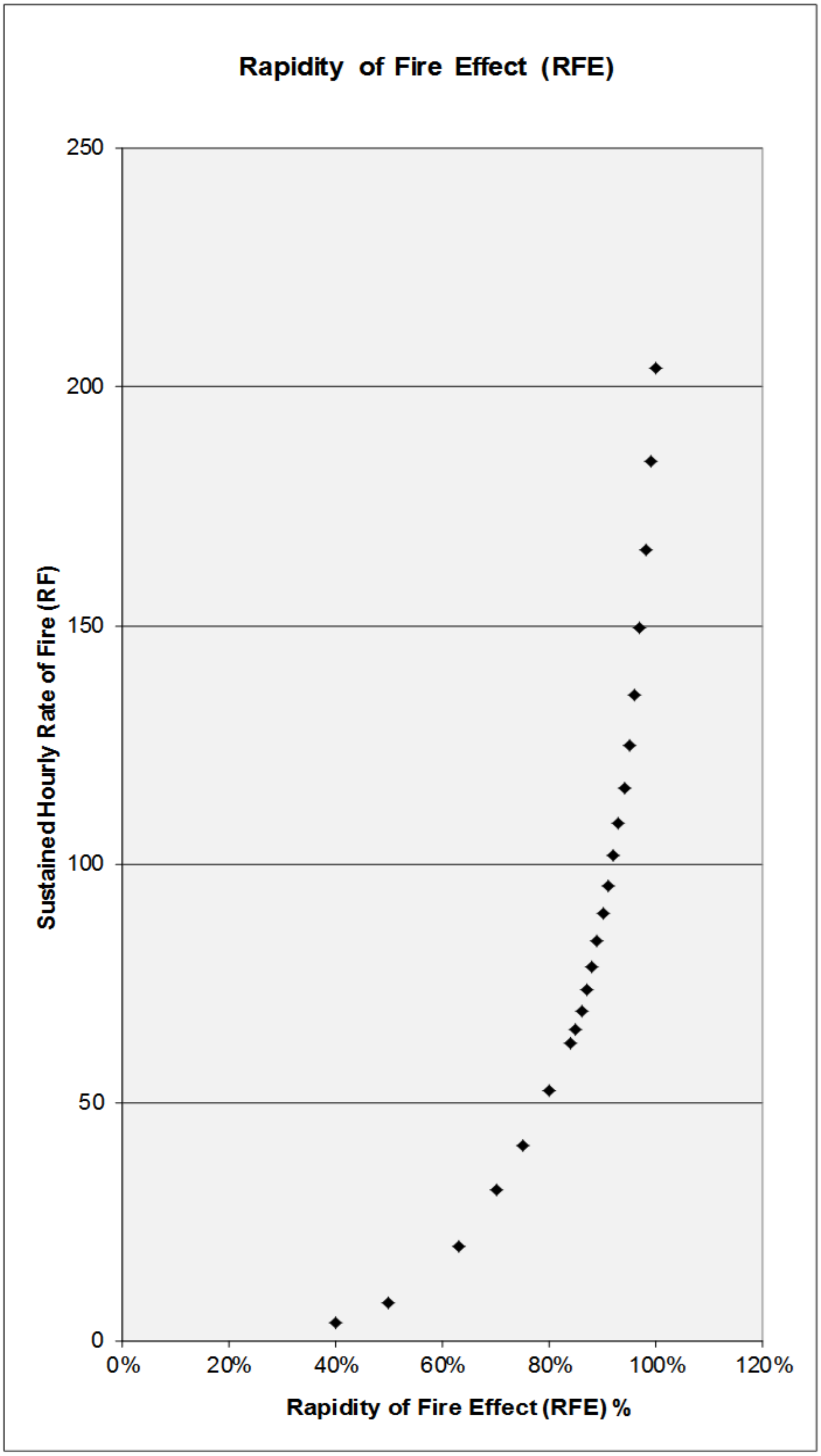
Graph RFE

Mobile Fighting Machine's (MFM's) Principal Weapon Rapidity of Fire Effect

RFE % (x)	Rate of Fire RpH (y)
40%	4
50%	8
63%	20
70%	32
75%	41
80%	53
84%	62
85%	65
86%	69
87%	74
88%	79
89%	84
90%	90
91%	96
92%	102
93%	108
94%	116
95%	125
96%	136
97%	150
98%	166
99%	184
100%	204



An important factor not yet considered within either the RF factor or RFE factor, specifically in relation to MFMs, is the reduction in rate of fire due to having ammunition with separate warhead and charge. [217] This is particularly critical in tanks and assault guns, with very limited available space and hence only one loader.

During WWII most AFV ammunition came in one piece, so the loader could pick up and load the whole round in one go. For calibres over 110mm the round becomes very heavy and large. For AFVs with guns over this size there arises the multiple problems of ammunition storage, manhandling such a large round in a small space, and the maximum weight that can be manually lifted. One way to reduce the problems related to excessively large rounds is to load the warhead (shell) and propellant (the charge) separately. This increases the number of rounds which can be stored and reduces the load on the loader. It also results in a severe reduction in the rate of fire because the loader has to effectively locate ammunition and load the gun twice per round fired. In addition they may have to 'ram' the shell to make room for the charge. Separate ammunition is common in medium and heavy artillery, but these weapons have a large crew. In these cases several crewmen can lift and load each shell and charge, additional crewmen can ram the shell if required, and ammunition stowage is not a problem with yet more men bringing ammunition forward to the weapon. For artillery the normal RF factor already effectively includes separate ammunition in larger calibre weapons.

MFMs with separate ammunition and only one loader have their RFE factor multiplied by 0.8, and MFMs with separate ammunition and two loaders have their RFE factor multiplied by 0.9, to take account of this effect.

The only significant AFVs in WWII which suffered from this effect were the IS-2 with a four man crew, and SU-152, ISU-122, ISU-152 and Sturmpanzer IV with five man crews. [218] All these AFVs were direct fire weapons designed primarily for the assault role. [219] This goes some way to explaining why combat accounts of these vehicles successfully surprising and engaging multiple enemy tanks are non-existent. Most major tank,

assault gun and tank destroyer types in WWII, have combat accounts of a single AFV inflicting damage on numerically and possibly qualitatively superior enemy AFVs. This is often due to surprise, ambush or some similar tactical reason. In these situations a reasonable rate of fire is essential because the firer needs to inflict maximum damage on multiple targets in minimum time (i.e. before they can recover). The firer needs a lot better than around two rounds per minute, which was common in WWII AFVs with separate ammunition. [220] This is also one of several reasons why these apparently powerful vehicles had relatively poor kill ratios against enemy AFVs. It should be said however that their kill ratio against dug in defences (where they could stand off at medium range) was good, and this is what these vehicles were primarily designed for.

Other factors which can dramatically affect rate of fire are: the tank commander doubling as the loader or gunner, the presence of a turret basket (both factors included in Fire Control Effect (FCE) below), and the design of the ammunition stowage in the AFV. Ammunition stowage layout and design is not specifically factored into our MFM OCPC calculations. Generally tanks with smaller internal volume have reduced efficiencies in this area. For example, in the IS-2 a portion of the ammunition propellant (charge) was stored in boxes such that the box roofs became the turret floor. When opened, the loader and other turret crew had to side step open ammunition boxes to move around the turret. At the same time the gun rotated above the loader, independent of his orientation, as there was no turret basket. Given all these factors, and its two piece ammunition, it is not surprising the IS-2 had such a low rate of fire. [221]

For APCs (Armoured Personnel Carriers) the RFE effect is not considered and is automatically given a value of 1.

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h. Fire Control Effect (FCE)

The FCE is a direct measure of the ability of a MFM to newly acquire, track and hit any stationary or moving target. This effect is independent of crew training (their tactical combat proficiency) and is inherent in the

technology and design of the individual weapon system. The FCE is a large component in the overall firepower of the MFM. [222]

It is often said that a successful tank design is good balance of mobility, protection and firepower. In general during WWII, the Soviets tended to focus more on mobility and protection while the Germans tended to focus more on overall fire power. Overall firepower is not simply the gun's ability to penetrate armour or its shell weight. The German Army in WWII essentially believed that it was vital to hit your opponent before they could hit you, and if this was not possible, to ensure that they were hit much more frequently. They believed a better defence than armour to survive a hit, was not to get hit at all. As they developed far more powerful tanks with good protection and/or mobility, such as the Tiger and Panther, the Germans still maintained all the fire control features from earlier models. Even more than the armour on these tanks, it was the fire control efficiency that made these tanks so lethal, particularly at medium to long range.

As the war progressed the power of AT weapons became such that any hit was likely to be fatal, so this philosophy became even more valid. The Soviets and Western Allies copied many of the German fire control systems and turret ergonomics, and implemented them in their late and post-war designs. Not until 1944 did the Soviets start to implement features to improve fire control; such as three man tank turrets or turret cupolas. Today the three man turret is standard in modern main battle tanks. In addition, the philosophy of 'hit first' is now considered so vital that modern tanks have a much higher portion of their cost and volume devoted to sophisticated fire control systems than equivalent WWII tanks.

It is interesting how many authors and military simulations still base protection on frontal armour and slope, mobility on top speed, and firepower on the shell weight and penetrative ability of the gun carried. Unsurprisingly, the values calculated using this simple method almost never match the actual tactical combat kill/loss ratios achieved by these vehicles. Of the three parameters protection, mobility and fire power, it is the latter that is the most ignored, misunderstood, unknown and subtle. Yet within the firepower parameter lies one of the most important secrets of true combat

capability. It goes a long way to explain why some AFVs historically performed much better than others at the tactical combat level. [223]

***

The effectiveness and survivability of any MFM in rapidly changing combat situations depends largely on the efficiency of the crew. This is particularly true for tanks or similar AFVs. In this regard the turret crew is especially critical as the turret contains the fire control systems, the command functions and all the main weapons. [224] The turret crew needs to fulfil several critical functions simultaneously during combat. The key word here is 'simultaneously', or as close to as possible. These functions include the following.

i. The turret crew must coordinate their movement and fire control on the battlefield with other vehicles in their platoon, and other weapons outside their immediate organisation (e.g. supporting infantry). This is principally the vehicle commander's job. He is assisted by various devices in the turret and by not trying to do too many other jobs simultaneously. Note, this does not include the presence or absence of inter-vehicle communication (radios) as this is considered a platoon/company level tactical activity, which is considered to be outside the individual weapon system. [225]

ii. The turret crew must identify (acquire) new threats and targets early, feeding this information to other crew and platoon members as quickly as possible. This is also principally the vehicle commander's job, although other crew members obviously contribute information if they have suitable vision and communication devices.

iii. The turret crew must be able to track the newly identified target and quickly train their main weapons onto the target. This relies largely on efficient turret traverse and optical systems, but there are also other devices in tanks to speed up this process (including WWII era tanks, refer below).

iv. The crew must select and load appropriate ammunition, and be able to quickly change this selection as new target types appear. This is a

usually a coordinated effort between the commander and loader. The commander should identify the target type and bearing, advising the gunner and loader. Obviously the gunner may also identify the target type and advise the loader directly. The loader should organise the ammunition so different ammunition can easily be selected, and the turret layout should facilitate this.

v. The crew must be able to hit the target with as few shots as possible. Once the target is being tracked and appropriate ammunition loaded, the gunner has to hit the target. This is the principal job of the gunner. It is largely dependent on the optical systems, which includes any range finders and accurate, aligned and calibrated gun sights. In addition, refinements such as course and fine turret traverse can greatly assist the gunner.

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In order to calculate the vehicle's FCE factor we will include the following five sub-factors. Turret Crew Efficiency (TCE), Main gun Optics Quality (OPQ), Turret Basket Effect (TBE), Rotating turret present or not and if present Turret Drive Reliability (TDR), and Target observation and Indicator Devices (TID).

For MFMs the Fire Control Effect (FCE) is given by,

$$FCE_{MFM} = TCE * ((0.5 * OPQ) + (0.1 * TBE) + (0.3 * TDR) + (0.1 * TID))$$

All the sub-factors range in value from 0 to 1, so the reader can quickly see from the equation above the relative weighting given to each sub-factor.

For APCs (Armoured Personnel Carriers) the FCE effect is not considered and is automatically given a value of 1.

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i. Turret Crew Efficiency (TCE)

The Turret Crew Efficiency (TCE) is dependent on the number of crew in the turret, their allocated job functions and the ergonomics of the turret layout.

In many small AFVs such as the Soviet tankettes, the German Pz I, the British Infantry Tank Mk1 and many armoured cars, only one person could fit in the MG armed turret. In these cases the turret occupant was also the vehicle's commander. He was responsible for traversing the turret, reloading the MGs, aiming and firing, and making the tactical decisions. With MGs, loading was only needed intermittently and the turret was usually light and relatively easy to traverse. However the turret workload was already too heavy for one person and two man MG turrets were obviously more efficient. Fortunately many of these machines had tactical reconnaissance roles and were not meant to be in intense combat, so the weapons were primarily there for self-defence.

In other WWII AFVs the turret guns were much larger than MGs and they were designed for combat, but they still only had one crew member in the principal turret. Three famous examples are the French Renault R35, Hotchkiss H-35/38/39 and the Somua S-35. [226] These tanks had guns ranging in calibre from 37mm to 47mm. They generally had thicker armour than the German light and medium tanks of 1940, and their guns had reasonable performance. However, the single man turret design was almost certainly the biggest weakness in all these tank types. This weakness (along with the mistaken French tank doctrine of distributing most of their tank forces amongst their infantry forces) was the major cause of their dismal tactical performance in 1940.

Imagine for one moment the workload of one of these tank commanders. A group of Renault R35s were driving along looking for the enemy, when their commander suddenly saw some enemy tanks. He had to promptly advise the other tanks, then drop down into the turret, find and load the appropriate ammunition, hop into the gunner position, traverse the turret onto the target (which had probably moved), find and adjust for range (adjusting his eyes to the optical instrument after gazing into the distance for some time without these instruments), fire and observe the fall of shot (difficult through many optical gun sights), get out of his position, load the

gun again, etc. In the meantime the tank was oblivious to the other tanks in the group and what the enemy was doing tactically. In short, an unmitigated disaster; and in hindsight hardly surprising that the German tanks used them for target practise.

As the turrets and guns got larger, the one man turret became impossible and so the two man turret was used. [227] However this proved to be only marginally better than a one man turret. The essential problem with the two man turret was that the commander doubled as the gunner. This meant that most of the tank's command and control (as well as the tank platoon's command and control) almost ceased to function once the action started. The commander had to concentrate on bringing the gun to bear onto an identified target, getting the correct range and hitting the target. While this was going on, other tanks in the platoon operated completely independently. Even worse, new targets and threats appeared without the commander or crew being aware of them and the enemy's tactical movements went unnoticed. In Soviet tanks without radios and using flags to signal each other, the commander was expected to leave his gunnery position, find his signal flags, clamber to the turret hatch and wave/signal to other tanks in the platoon. While all this was happening the tank wasn't engaging any targets with its main weapons. Of course this workload was practically impossible, and in action these Soviet tanks effectively remained out of communication with each other and often 'buttoned' up (i.e. with the hatches closed up). The practical result was that Soviet tank platoon tactics revolved around all the tanks in the platoon following the platoon leader, and often all engaging the same target. Meanwhile the enemy took unseen or unnoticed steps to annihilate the platoon. In two man turrets, almost all the critical functions that needed to be carried by the turret crew during combat were compromised; some of them very severely.

The most famous examples of tanks with two man turrets are the vaunted Soviet T-34/76 tank, the almost equally praised Soviet KV-1 tank, and the more maligned Soviet T-26 and BT series of light and fast tanks. [228] All these tanks had larger 45-76mm guns, which only served to exacerbate the problems with two man turrets. The British came off only slightly better with the Infantry Tank Mk III (Valentine), Tetrarch light tank and Crusader III. All these tanks had two man turrets and a 40mm (2 pdr) or 57mm (6

pdr) gun. Some of the other British cruiser and infantry tanks had very cramped three man turrets, which were barely able to take advantage of the extra turret crewman. Examples are the Cruiser Mk V (Covenanter) and the Crusader I. The French Char B-1 and B-1 bis, the heaviest tanks on any side in the 1940 French campaign, also had a two man turret. [229] The only significant German tanks with two man turrets were the Pz Mk II with a 20mm gun, and the Pz 35(t) and Pz 38(t) with 37mm guns. The Pz Mk II was never meant as a battle tank. It was designed for reconnaissance and light 'contract', and the 20mm cannon was loaded with a ten round magazine so the loader's role was minimised. The Pz 35(t) and Pz 38(t) were commandeered Czech tanks. When the Germans took over these tanks they increased the turret crew with an additional loader, which relieved the tank commander from running a single man turret. To accomplish this, the amount of 37mm ammunition carried in the Pz 38(t) was reduced by 18 rounds to make room for the loader. [230] However the basic turret was simply too small for a third turret crew member, and both the Pz 35(t) and Pz 38(t) suffered accordingly from having only two man turrets.

Very early on the Germans realised that the three man turret was the only way to go. The commander's role was seen as especially critical and a full time job. The Germans decided that the tank commander shouldn't normally be operating any weapons directly, and his function was seen as so important that additional vision and communication devises were added to assist in his command and control function. The gunner and loader were also dedicated tasks, and any design needed to provide them with the relevant tools and sufficient room to perform their specialised tasks efficiently. Similarly, the driver and forward machine gunner/radio operator were seen as dedicated tasks. All crew members usually had access to some vision devices, and communicated via a throat microphone and intercom system. This ergonomic arrangement remains the basis of the turret layout in the modern main battle tank; close to seven decades later.

The very first German Pz Mk IIIA, produced in 1937, had a five man crew and three man turret. This became the standard configuration in all German main battle tanks during WWII. The first StuG IIIA assault guns (without a rotating turret), produced in 1940, also had a three-crew fighting compartment in the same configuration as the tanks. This also became the

standard in German fully enclosed and turretless tank destroyers. By contrast the first standard Soviet tank to enter service with a dedicated three man turret was the T-34/85 in the March 1944. [231] In these tanks the crew were organised as per German tanks. The Soviet tanks that followed all had the same three man turret configuration, including the IS-2 and IS-3. The British appear to have been the first Allied power to appreciate the importance of the three man turret. The Infantry Tank Mk II (Matilda) had a three man turret in service from 1939/40, while the Infantry Tank Mk IV (Churchill) had a three man turret in service from 1941. Several of the early war British cruiser and infantry tanks had small turrets and turret rings but they still insisted on ‘cramming’ three men in, so they had obviously decided this was very important. The British had standardised on the three man turret and five man tank crew configuration by 1943/44 with their Centaur IV, Cromwell, Challenger and Comet designs. The US M2A4 and M3 light tanks had two man turrets. But the M4 (Sherman) was designed from the beginning with a five man crew and three man turret, and entered service from 1942.

In order to establish the effect of turret crew numbers on the Turret Crew Efficiency (TCE), we will use the following matrix.

The Effect of Turret Crew Numbers on TCE			
Turret crew number	Turret with LMGs only	Turret with gun 10-24mm	Turret with gun > 24mm
1	0.85	0.75	0.55
2	1.00	0.85	0.75
3	1.00	1.00	1.00
4+	1.00	1.10	1.10

The matrix takes into account that the impact of one or two man turrets in light tanks and armoured cars (armed with small calibre and sometimes automatic guns), is much less than the same configuration in main battle tanks with large calibre guns.

ii. Main gun Optics Quality (OPQ)

Main gun Optics Quality (OPQ) is a measure of the relative quality of the MFM's main gun optical aiming and range finding devices. These include any separate range finders and any range finders built into the main gun sight. The OPQ sub-factor includes alignment and calibration of the sight and the gun.

During WWII the Germans enjoyed the products of the finest optics industry in the world at that time. The optical gun sights on most German guns and AFVs were superior to the sights on equivalent Western Allies weapon systems, and markedly superior to all Soviet ones to the end of the war. For direct fire weapons there were two main advantages. Firstly they enabled considerably increased accuracy over distances greater than 700 metres. Secondly they enabled more rapid target acquisition and accurate range determination at all ranges. As the power and effective range of AT guns increased during the war the optical systems also improved. This enabled tanks such as the Tiger and Panther to be lethal between 2,000 and 3,000 metres. [232] On the East Front the Soviets were rarely able to win a long range gunnery duel. Their policy was not to waste ammunition and to close the range to between 500 and 800 metres. Even late war tanks such as the IS-2 did not enjoy optical systems as good as those on the Pz IV Ausf G-J. Given this, it's pointless simply comparing the armour penetration of the guns on these AFVs (at set ranges) to determine their relative anti-armour capability: optical gun sight quality has to be factored in.

Two weapons deserving special mention here are the Nashorn (later called *Hornisse*) and 88mm Flak 18/36. The Nashorn carried the 88mm PaK 43 L/71 gun and its ZF3x8/Rblf36 gun sight enabled it to engage armoured targets out to a phenomenal 5000 metres. One of the reasons the 88mm Flak 18/36 developed such a fearsome anti-tank reputation was its optical aiming systems, which were designed from the outset to engage both air and land targets at long range. The 88 FlaK 18/36 could engage land targets effectively at 3000 metres. In effect, whatever target the crew of the '88' could see to aim at, they had a good chance of actually hitting. [233] In this regard it enjoyed superiority over the British 3.7in Mk1 AA gun which was not used in the anti-tank role, and a marked superiority over the Soviet 85mm M1939 AA gun.

iii. Turret Basket Effect (TBE)

Turret Basket Effect (TBE) determines whether the MFM receives the benefit of a turret basket. A turret basket means the floor if the turret is attached to the turret walls, and rotates with the turret and gun. The TBE value used in our FCE calculation is either 1 (present) or 0 (absent). There are several benefits to having a turret basket which include the following.

i. The loader can load the main gun whilst the turret is rapidly rotating. This is particularly true for heavy rounds in larger guns. For example, the Panther tank could rotate its 75mm gun turret 360 degrees in 15 to18 seconds. [234] Any loader would have great difficulty loading a 7-8kg round while the gun's breech was moving around his position at that speed; especially without getting seriously injured. This increases the rate of fire.

ii. The loader does not have to continuously monitor the position of the gun's breech relative to his position. He is more often in position to load the round with appropriate ammunition, especially if benefit iii. (below) is used. This increases the rate of fire.

iii. The loader can place selected ready rounds on the turret basket floor, depending on the tactical situation. This enables him to rapidly load the gun with appropriate ammunition independent of turret position. This increases the rate of fire and speed of ammunition change.

iv. The gunner can stand in one position, aim the gun and rotate the turret without having to move himself around with the rotating turret. Note, most gunners sit in a small seat attached to the turret wall. However certain situations will demand he stand, such as having to use a heavy manual turret traverse system. This reduces target acquisition time and increases accuracy.

v. The risk of injury or death to the turret crew is greatly reduced. The commander and particularly the loader are at risk when standing on a fixed floor with the turret machinery moving around them. For example, if the gunner quickly traverses and fires, the gun recoil is far more likely to hit any person inadvertently out of position.

vi. Having a turret basket prevents ammunition stowage under the turret floor, and requires ammunition stowage in the turret or hull wall-spaces. Generally tanks with low height and less internal volume attempt to save space by not having a turret basket. These same tanks also have more problems stowing ammunition and the turret floor often becomes a storage area for ammunition. However the turret crew need a floor to operate, so rounds are stored in ammunition boxes with lids which become the turret floor when the boxes are closed. The loader has to open the box with the correct ammunition, load the gun which may be rotating about his head, and either close the box or remember not to trip over the open box on the turret floor. Several open ammunition boxes on the turret floor will soon render the whole space inefficient and dangerous. Generally ammunition stowage in the turret or hull wall-spaces increases the sustained rate of fire.

Despite all these benefits, the contribution of a turret basket in enhancing the MFM's fire control is considered to be relatively small in our overall FCE calculations. The Germans first used turret baskets in the Pz III Ausf H, and this was subsequently retro fitted to the Ausf E, F and G. [235] All German tanks subsequently had turret baskets, as did the Sherman tank. No Soviet tanks produced during their war with Germany were fitted with turret baskets.

Assault guns and other turretless AFVs with 'fixed' guns are viewed as getting the benefit of a turret basket, i.e. their TBE value is 1. This is because the floor of the fighting compartment moves very little relative to the gun's traverse. For example, the gun in a StuG III A-E had a traverse of only 12 degrees to the left and right of its centred position.

iv. Turret Drive Reliability (TDR)

Turret Drive Reliability (TDR) determines if a rotating turret is present or not, and if present the TDR is a measure of the turret drive system's contribution to the overall MFM's fire control efficiency.

If the MFM is an assault gun or other turretless vehicle, then the TDR value is zero. This means that turretless AFVs which received benefits from not having a turret, such as increased armour, larger guns and lower

silhouette, are now paying the price with a significantly lower fire control efficiency (which translates into lower FCE values). For these purposes the limited ability of the gun to move left and right in its mounting are not considered.

For MFMs with rotating turrets a value is placed on the turrets drive's reliability, speed of operation, and course and fine adjustments. In general during WWII the German and Western Allied turret drives were of similar quality, while both were marginally better than Soviet systems.

For German and Western Allied AFVs with a rotating turret, the base TDR vale is 0.75 for hand, 0.80 for electric and 0.85 for electric-hydraulic traverse systems.

For Soviet AFVs with a rotating turret, the base TDR vale is 0.7 for hand, 0.75 for electric and 0.80 for electric-hydraulic traverse systems.

Any additions to these base TDR values, there may be some small additions for more reliable or better designs (particularly those with a reliable powered fine-adjustment capability, which receive a 0.01 to 0.03 bonus).

v. Target observation and Indicator Devices (TID)

Target observation and Indicator Devices (TID) is a measure of the quality and design of observation devices available to the tank's crew apart from the gunner, and the presence of other devices inside the vehicle which assist the gunner to more rapidly acquire the target. In addition, any vehicle design features hindering observation are included, which would reduce the TID value.

To a large extent TID features on a MFM go hand in hand with the appreciation of the importance of the three man turret, particularly the key role of the commander. In battle German tank commanders preferred, and were trained, to ride with their head protruding periodically from the open turret hatch so they could better observe the battlefield. [236] Obviously this carried risk to the commander and was sometimes impossible to do safely. With this in mind the Germans gave most of their AFV commanders a

turret cupola (around the main turret hatch) from the beginning of the war. The turret cupola consisted of a circular armoured wall protruding from the turret roof, fitted with armoured glass vision slits or periscopes. The turret cupola enabled the commander to get an almost 360 degree field of view even when the hatch was closed. Even early German light tanks like the Pz II had a turret cupola with eight periscopes. The Czech Pz 35(t) and Pz 38(t) also had turret cupolas, although with lower numbers of vision slits. Subsequently all German main battle tanks had turret cupolas, as well as many assault guns and tank destroyers. Early assault guns and several late war tank destroyers did not have cupolas, although they often had periscopes protruding from the roof. The Germans also provided turret-wall vision ports with armoured glass in most tanks, and there were sometimes additional periscopes for other crew members to use.

The first Soviet AFVs to receive a proper turret cupola were a few late Model T34/76 Model 1943s, and then the T-34/85 in the spring of 1944. [237] Subsequently the IS-2 heavy tank and late model SU 85 and SU-100 tank destroyers also had prominent cupolas for the commander's use. Surprisingly, the IS-3 (from mid-1945) had no turret cupola and reverted to a single hatch periscope. Prior to this most Soviet main battle tanks had a simple rectangular or similarly shaped turret hatch that simply lifted up and forward. If present, vision slits in the turret or superstructure walls were often of poor quality with the armoured glass being full of air bubbles. [238] Periscopes for non-commander crew members were few and far between. As an example let us examine the vision devices on the highly rated T-34/76 Model 1941 and Model 1942. These tanks were the best and most common Soviet tanks of that period, and still rated by many WWII commentators as the best designed medium tanks in service in the world from 1941 to mid-1943.

As already stated many German tank commanders liked to fight with their heads out of the turret for a 360 degree view (or, if the situation was too dangerous for this, they at least had the use of a turret cupola with all round vision). On T-34 Model 1941/42s the one-piece turret hatch encompassed the full width of the turret roof, and was to be used by both the tank commander and loader, as well as being the whole crew's main escape hatch. The hatch was lifted forwards to the open position, and, as it

constituted a large part of the turret's roof armour, it was extremely heavy. If a T-34/76 commander attempted to ride into battle in the manner preferred by many German tank commanders (i.e. with his head periodically appearing above the turret roof), then his view was severely curtailed by this large forward opening hatch. The T-34 commander was therefore obliged to completely expose himself and literally sit on the turret roof, risking not only enemy fire but also injury from the heavy hatch. In addition, as the hatch extended the full width of the turret roof, an open hatch exposed the entire turret crew to the effects of enemy fire. The result of all this was that when the action started, T-34 commanders almost always closed down. Even if this was not the preferred doctrine of the Red Army tankers, the T-34's turret design gave them little choice. [239]

Once inside, the commander and loader were each supposed to have a PT-6 periscope projecting through the turret roof. Although meant to be panoramic telescopes they offered a narrow field of view with dead zones all-round the tank. The periscope for the loader was deleted on most T-34/76 production due to war time shortages. Both the commander and loader were provided with a fixed viewing port on the turret side. Thus on most T-34/76s in a closed down mode the commander had a periscope, one fixed side viewing port and the main gun's TOD-6 telescopic gunsight, while the loader had one fixed side viewing port. [240] It could be argued that the commander didn't need the periscope or viewing port anyway as he spent nearly all his time looking through the gun sight trying to acquire and hit a target!

***

Apart from optical gun sights and vision devices, there were other devices which served to enhance the MFM's overall fire control efficiency in WWII. Probably the most important for consideration here is the 'target indicator system' used between the commander and gunner in many German tanks. Around the inside of the commander's cupola was a scale marked from 1 to 12 with 24 sub-divisions. When the turret was traversed a pinion, which engaged the teeth of the turret rack, drove the scale in the *opposite* direction but at the same speed, so that the figure 12 remained in constant alignment with the hull's centreline, looking directly forward. This

enabled the commander to determine the precise bearing of his next target and inform the gunner accordingly. To the gunner's left was a repeat target position indicator in the form of a dial identically marked to the cupola scale, and also driven from the turret rack. Upon receiving the order, the gunner would quickly traverse the turret onto the bearing indicated, and find the gun approximately on line for the target. [241] This type of fire control system was the forerunner to the far more sophisticated electronic systems used on tanks today. Soviet tanks in WWII don't appear to have had any such target indicator systems fitted (after all, such a system might have reduced production).

***

So what was the end result of the T-34/76's two man turret, weaker optics, poor vision devices, and negligible 'target indicator systems' (i.e., a poor overall FCE factor)? German tankers noted "T34s operated in a disorganised fashion with little coordination, or else tended to clump together like a hen with its chicks. Individual tank commanders lacked situational awareness due to the poor provision of vision devices and preoccupation with gunnery duties. A tank platoon would seldom be capable of engaging three separate targets, but would tend to focus on a single target selected by the platoon leader. As a result T-34 platoons lost the greater firepower of three independently operating tanks". [242] The Germans noted the T-34 was very slow to find and engage targets while the Panzers could typically get off three rounds for every one fired by the T-34. [243]

A combat account from Operation Barbarossa highlights the problem with the T-34/76's fire control systems and also why its overall combat power is so overrated. "Remarkably enough, one determined 37mm gun crew reported firing 23 times against a single T-34 tank, only managing to jam the tank's turret ring". [244] In this engagement T-34 proponents will highlight the impunity of the T-34 to the 37mm Pak 36 AT gun. However this is hardly surprising against a gun that can only penetrate 29mm of 30 degree sloped armour at 500metres with ordinary AP ammunition. What is really important in this story is that the AT gun managed to get 23 shots off, and it turns out that the T-34 in this report didn't even manage to hit the AT

gun. Once better AT guns appeared, which they rapidly did, T34s would be lucky to survive 2-4 rounds. Contemporary German tank crews would have been be appalled if they let enemy AT guns get more than two rounds off before they took defensive action. This example highlights the difference between tanks designed to optimise all their fire control related systems and hence maximise their firepower; and those that were not. [245]

i. Ammunition Supply Effect (ASE)

We now come to the third of four factors which enhance the offensive and defensive power of the vehicle. The Ammunition Supply Effect (ASE) is a measure of the ability of the MFM to remain in combat due to ammunition considerations.

The ASE factor is important in the overall combat power of any AFV, particularly tanks, assault guns and tank destroyers. This is because the ammunition is all carried on board. In most tactical situations, the moment the AFV runs out of ammunition it goes from being a battlefield asset to a liability. In some tactical situations, such as defending a position against a numerically superior force, this can be fatal to the defence. This is because in most combat it is simply impractical for the AFV to withdraw to a supply area, rearm and return to battle. By then the tactical situation has usually changed. Similarly in attack, once the AFV's ammunition is used the attack is usually over (or at least temporarily halted) if the attack largely depended on the AFV's support.

Vehicles classified as self-propelled weapons also carry ammunition on board. [246] Generally this type of vehicle is not involved in the same type of combat as AFVs, and comes under much less direct fire. These vehicles often have immediate support vehicles carrying ammunition, which are themselves sometimes armoured. For these vehicle types the ASE factor is considered to be 1. [247]

The ASE factor is calculated based on the amount of ammunition the machine can carry as a percentage of the theoretical hourly sustained rate if fire, or RF factor. The Rate of Fire (RF) factor has already been considered

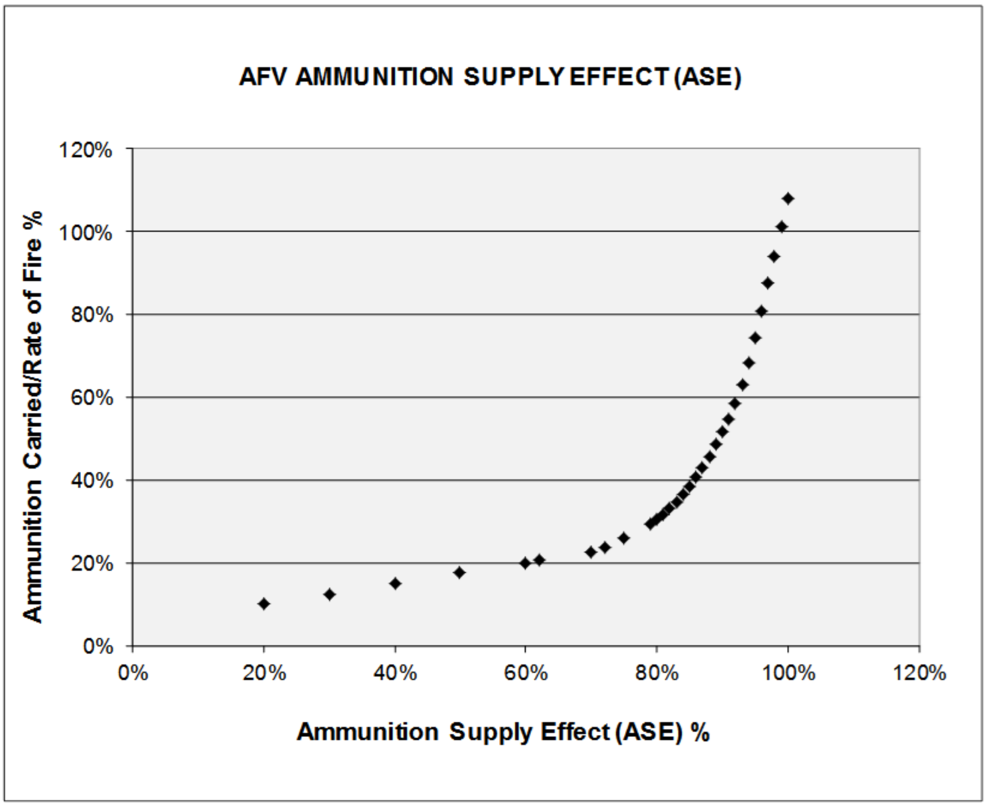
for the principal weapon on the MFM when calculating the weapon's WCPC.

Graph ASE shows the relationship between the ratio of ammunition carried over Rate of Fire (RF) expressed as a percentage, against the Ammunition Supply Effect (ASE) factor also expressed as a percentage.[248]

Graph ASE

ASE % (x)	Ammo/ Rate of Fire % (y)
20%	10%
30%	13%
40%	15%
50%	18%
62%	21%
60%	20%
70%	23%
72%	24%
75%	26%
79%	29%
80%	30%
81%	32%
82%	33%
83%	35%
84%	36%
85%	38%
86%	41%
87%	43%
88%	46%
89%	49%
90%	52%
91%	55%
92%	58%
93%	63%
94%	68%
95%	74%
96%	81%
97%	87%
98%	94%
99%	101%
100%	108%

AFV Ammunition Supply Effect (ASE) Factor



Generally speaking, AFVs with an ASE above 0.85 (85%) are going to find they have sufficient ammunition to last for most engagements. Most WWII tanks had ASE ratings from 0.85 to 0.95. One notable exception was the IS series of tanks and assault guns. The IS-2 and IS-3 tanks carried only 28 main gun rounds in total, and as they were engaging mostly non-armoured targets they probably carried fewer than 10 rounds of armour piercing ammunition. If in combat with enemy armour, the IS-2 would effectively have to withdraw (if it could) after firing only around 10 rounds.

The overall ASE factor for the IS-2 comes in at 0.79 and was a significant tactical weakness in these tanks. By comparison the Tiger I, Panther and T-34/85 had ASE ratings of 0.94, 0.90 and 0.85, respectively.

For APCs (Armoured Personnel Carriers) the ASE effect is not considered and is automatically given a value of 1 (100%).

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j. Half Track-Wheeled Effect (WHT)

The last factor which affects the offensive and defensive power of the vehicle is the Half Track/Wheeled Effect (WHT) factor.

To a large extent the WHT factor is a correction to the vehicle's Battlefield Mobility Factor (MOF), which only considers power to weight ratio. The MOF factor takes no account of whether the vehicle is fully, half or non-tracked. Fully tracked vehicles have their cross-country mobility and protection (no tyres) enhanced to a large degree by being fully tracked. The one exception in 1941 was the German Sd Kfz 231/232 and 263 eight wheeled armoured cars. These were very sophisticated, expensive and hard to produce vehicles, capable of going anywhere a tracked vehicle could go.

WHT factors apply as follows, [249]

- Fully tracked vehicles, and Sd Kfz 231, 232 and 263 armoured cars, have WHT factor = 1.
- Semi-tracked vehicles, including APCs, have WHT factor = 0.95.
- Wheeled vehicles, have WHT factor = 0.90.

***

4) Calculating an Aircraft's Overall Combat Power Coefficient (OCPC)

Aircraft include fighters, fighter-bombers, ground attack/close support aircraft, bombers, short range reconnaissance/army cooperation aircraft,

long range reconnaissance aircraft, coastal aviation/patrol/anti-ship aircraft and transport aircraft.

The following factors are considered in calculating all aircraft OCPCs. All aircraft mounted and aircraft launched Weapon Combat Power Coefficients (WCPCs) calculated as in the first step (refer Part II 2. 1)), Battlefield Mobility Factor (MOF), Radius of Action (RA), Aircraft Durability Factor (DUR), Aircraft Shape and Size Factor (SSF), Maximum speed and Manoeuvrability Factor (SpMvr) and Ceiling Effect Factor (CL). [250]

For aircraft the Overall Combat Power Coefficient (OCPC) is given by,

$$OCPC_{Aircraft} = \left(\left(\sum_{1}^{MBE + Air\ L\ Wpns} WCPC_{Aircraft} * MOF * RA \right) + \left(DUR * SSF * SpMvr \right) \right) * CL$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all aircraft mounted weapons on the aircraft, added up using modified Multi Barrel Effect (MBE) rules, and the simple sum of WCPCs for all aircraft launched weapons (bombs and rockets).

The reader should note that the factors WCPC, MOF and RA are essentially offensive components, while DUR, SSF and SpMvr are essentially defensive components. [251] Factor CL enhances both the offensive and defensive power of the aircraft. Hence the overall combat power is the enhanced sum of the offensive and defensive elements.

***

a. Aircraft Mounted Weapons and Multi Barrel Effect Rules

Aircraft mounted weapons are defined as any permanently mounted aircraft weapon systems, which fire high velocity projectiles. These weapons have their WCPC values degraded by an Aircraft Mounted Weapon Effect (AE). [252]

For calculating the aircraft's OCPC, all the individual aircraft mounted weapon WCPCs on the aircraft are added together using slightly modified

Multi Barrelled Effect (MBE) rules. [253] The MBE effect does not apply to the first or principal aircraft mounted weapon on the aircraft. However it applies to all weapons after the first one.

For example, consider the Messerschmitt BF109E-4. This aircraft has 2x20mm MG FF/M Cannon mounted behind the propeller and 2x wing mounted 7.92mm MG17 machine guns. [254] The 2x20mm MG FF/M Cannon mounted behind the propeller each have a WCPC value of 0.78, while the 7.92mm MG17 mounted on the wing each have a WCPC value of 0.2. The total 'aircraft mounted weapon WCPC' is then = 0.78 + 0.78 + (0.2x0.5) + (0.2x0.33) = 1.72.

When calculating the aircraft's 'aircraft mounted weapon WCPC' value, the primary weapon is always first, followed by the remaining weapons in order of decreasing WCPC values.

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b. Aircraft Launched Weapons

Aircraft launched weapons are defined as weapons where the entire weapon leaves the aircraft such as free-fall bombs or rockets. These weapons are not affected by the Aircraft Mounted Weapon Effect (AE) factor.

For calculating the aircraft's 'aircraft launched weapon WCPC', all the individual aircraft launched weapon WCPCs on the aircraft are simply added together. For aircraft which can carry a multitude of different types of bomb load, the most common bomb load is used. If this is undetermined, a bomb load is used which best fits the space available in the bomb bay and any available external bombing racks, whilst not exceeding the aircraft's normal maximum bomb load.

***

c. Battlefield Mobility Factor (MOF)

The MOF factor is a measure of how mobile the aircraft is around the battlefield.

Similarly to land based Mobile Fighting Machines (MFM)s, one might use the maximum air speed of the aircraft as an appropriate measure of battlefield mobility. However aircraft mobility has to be considered in three dimensions to a much greater degree than land based machines, and there are several severe problems in using only the aircraft's maximum airspeed to represent the MOF factor. [255] These problems include the following.

i. The aircraft's maximum air speed takes no account of the difference in speed when the aircraft is armed (loaded for combat) or simply flying with fuel only and under ideal test conditions. A lot of technical information on WWII aircraft presents the aircraft's top speed under the latter conditions, or without stipulating the load carried. In bombers and ground attack aircraft this is especially critical as they have large differences in maximum speed depending on their bomb load. For calculating aircraft OCPCs we are more interested in the maximum air speed with a normal (standard) weapon and fuel load.

ii. The aircraft's maximum air speed takes no account of the difference in speed at varying altitudes. Some aircraft perform very well at high altitude, such as interceptor fighters, but are much slower at sea level. Other aircraft perform more consistently at varying altitudes.

iii. The aircraft's maximum air speed takes little account of the overall 'flight envelope' capabilities of the aircraft. These include its climb rate at varying altitudes, dive rate and turn rate. These factors are very important in determining an aircraft OCPCs, especially fighters.

Similarly to land based MFMs, we need a relatively simple parameter which would better represent an aircraft's true battlefield mobility than simply top speed. The most consistent and realistic results were obtained using the maximum horse power of all the aircraft's engines under normal operation, divided by the normal loaded weight. For multi-engine aircraft the total power is the sum of the power rating of each separate engine. In almost all cases the aircraft's power to weight ratio was proportional to the top loaded air speed, the variation in airspeed at varying altitudes, the

maximum climb rate and maximum dive rate. Interestingly enough the aircraft's power to weight ratio was often not proportional to the turn rate, although a high ratio does help. The turn rate depends far more on the particular aircraft's design and airframe structure. [256]

Once the aircraft's power/normal loaded weight ratio (in hp/metric ton) has been established, the MOF factor is determined using,

$$MOF_{Aircraft} = \sqrt{power \,/\, loaded \ \ weight_{aircraft}} * 0.35$$

It is important to use the normal loaded weight to calculate MOF because the empty aircraft weight is much lower and will severely distort the aircraft MOF factor. Aircraft never flew empty and are not much use unloaded (except in museums)! Also, the maximum horse power under normal operation should be used because aircraft engine power outputs vary considerably (e.g., on take-off with an overweight load, when dogfighting, etc). However if an aircraft engine is used continuously at absolute maximum power it will usually overheat and destroy itself (and probably the aircraft) in a fairly short time.

If data on normal loaded weight is unavailable then the maximum take-off weight can be used, but the power rating should then be the maximum power at take-off.

***

d. Radius of Action (RA)

The combat potential of any aircraft is affected by its operational radius of action, which is the distance it can travel to the target with a combat load and then return to base without refuelling. This Radius of Action (RA) is essentially part of the overall battlefield mobility of the aircraft and as such is an 'offensive' factor.

The maximum range of the aircraft carrying a normal or common combat load (referred to as normal range) should be used because the maximum range of aircraft vary tremendously depending on the mission

and load configuration. In addition, certain aircraft had drop tanks developed which increased their radius of action considerably.

Drop tanks raise a particular problem for determining aircraft RA factors because in WWII their use was common in certain aircraft types; specifically fighters and fighter-bombers. As there use was common, drop tanks should be considered part of a normal or common combat load. However fighter-bombers in WWII usually only carried drop tanks if they weren't carrying bombs. Fighters often carried drop tanks and released them when engaging in air to air combat. For these reasons the range of fighters includes the use of drop tanks if they were developed and common for that specific fighter model. The range of fighter-bombers does not include the use of drop tanks because their OCPCs are being calculated with a normal bomb/rocket load.

Once the aircraft's normal range (in kilometres) has been established, the RA factor is determined using,

$$RA_{Aircraft} = \sqrt{normal\ range_{Aircraft} / 2} * 0.08$$

***

e. Durability Factor (DUR)

The DUR factor is a measure of the aircraft's ability to sustain damage and survive. It is the first of three defensive factors used in calculating an aircraft's OCPC and to some extent is similar to the land based MFM's Protection Factor (PR).

With land based MFMs the possibility of using the weight of the vehicle to determine the PR factor was discussed. The problem is that armour is so dense and has such large mass that large MFMs may be heavy with relatively thin armour (thickness) while small MFMs may be heavy with very thick armour. Thus, although the vehicles are similar in weight, the smaller MFM is much better protected. Hence the PR factor for MFMs has to take into account the size of the vehicle and its actual armour thickness.

For aircraft we do not have this problem because the vast majority of aircraft carry very little to no armour (even compared to the lightest of armoured vehicles). In this case the weight of the aircraft is generally proportional to its size, the amount of material spent in strengthening the airframe, and the size of its engines. All these attributes lead to higher durability. Therefore to determine the aircraft's DUR factor we can utilise the 'empty equipped weight' of the aircraft with some minor adjustments for the specific aircraft design. The empty equipped weight of the aircraft includes the weight with permanently mounted weapons, but no fuel, aircraft launched weapons or other ammunition.

The adjustments for the specific aircraft design should include the following parameters.

1. The number of engines. Obviously aircraft which can keep flying after losing power to one or more engines are more durable.
2. The stressing and strengthening of certain types of aircraft airframes. In WWII dedicated ground attack aircraft, in particular dive bombers, had thicker wing sections and strengthened airframes to withstand the stress of violent low level manoeuvre and ground fire. In addition many short range reconnaissance and army cooperation aircraft were involved in ground support duties. These aircraft were also very durable for their weight and were designed to operate from rough forward airbases around the clock.
3. The presence of armour. In WWII only a few aircraft types carried any really significant armour. The most well know is the Ilushin Il-2 '*Shturmovik*' which was present in the VVS from June 1941 onwards. The Il-2 airframe incorporated an armoured shell which protected the crew, engine and fuel tank. Another example was the heavily armoured Henschel Hs 129. Significantly both aircraft were ground attack, close support and anti-tank aircraft. Their armour was predominantly designed to offer protection from ground MGs and hopefully light flak.
4. The presence of self-sealing fuel tanks. Self-sealing fuel tanks reduce the chances of a catastrophic fire or explosion when the aircraft is hit. Most countries had introduced this feature in their modern combat

aircraft by 1941, with Japan as the most notable exception. [257] Most of the German aircraft production in 1941 had self-sealing, or at least protected, fuel tanks. The status on Soviet aircraft in 1941 is unknown. It is unlikely many of the pre-1940 Soviet aircraft had this feature, particularly the bombers, and these aircraft mostly equipped the VVS (Soviet Military Air Force) in June 1941. [258] Due to the uncertainty of the presence of self-sealing fuel tanks and details on different country's fuel protection designs, this attribute is not considered in our aircraft DUR factor calculations. [259]

Once the aircraft's empty equipped weight (in metric tons), number of engines, main mission type and armour presence has been established, the DUR factor is determined using,

$$DUR_{Aircraft} = \sqrt{empty\ \ equipped\ \ wght_{Aircraft} * 2} + \left(1 * \left(En - 1\right)\right) + 0.5_{Air\ \ Type} + 1_{Aircraft\ \ Armoured}$$

where: *En* is the number of engines.

$0.5_{Air\ Type}$ is a fixed value of 0.5, only if the aircraft is classified as a ground attack, close support, short range reconnaissance or army cooperation aircraft type. Otherwise the value is zero.

$1_{Aircraft\ Armoured}$ is a fixed value of 1 if the aircraft carries sufficient armour protection over its vital areas to stop bullets with a calibre less than 10mm. Otherwise the value is zero.

***

f. Aircraft Shape and Size Factor (SSF)

The aircraft SSF factor represents the increase or decrease in protection as a result of the size and shape of the aircraft. The aircraft SSF factor is a judgemental factor determined from the wing span, length and height of the aircraft, and is essentially a measure of the target size presented to enemy aircraft and AA guns.

The aircraft SSF factor is much less significant to aircraft than the similar SSF factor is to land based MFMs. There are no attributes relating to ‘sloped armour’ or ‘shot traps’, and aircraft gain the majority of their defensive strength from other factors such as speed, manoeuvrability and climb rate. In evaluating aircraft SSF factors, particular emphasis is placed on the wing span as this appears to be the single dimension most representative of the overall size and bulk of the aircraft. In addition the wing span best represents the cross sectional area viewed by enemy aircraft attacking from behind, in front, below or above the defending aircraft, which are the most common attack angles in air to air combat.

In addition to the normal aircraft dimensions, biplanes and floatplanes incur an additional 5% reduction in SSF factor, and biplane-floatplanes incur an additional 10% reduction in SSF factor. This is to take account of the generally larger target area presented by these aircraft types.

***

g. Maximum speed and Manoeuvrability Factor (SpMvr)

The SpMvr factor is a measure of the aircraft’s ability to engage in and survive air to air combat. It is the last of the three defensive factors used in calculating an aircraft’s OCPC and there is no directly similar factor in land based MFMs.

It is very arguable that the SpMvr factor should be an offensive factor. This argument is strongest for fighters engaged in air to air combat, but for all other aircraft types their speed and manoeuvrability are mostly used to avoid enemy fighters and to a lesser extent flak. As the SpMvr factor is also a strong defensive component for fighters, it appears on balance that the SpMvr factor should be considered an overall defensive factor. To a large extent the overall offensive ‘flight envelope’ characteristics of the aircraft are already considered in the Battlefield Mobility Factor (MOF) and Radius of Action Factor (RA).

When reading accounts of air to air combat, particularly dogfights between fighters, many attributes come into play in determining the aircraft’s inherent air to air combat ability (assuming the pilots are all of the

same quality). They include maximum level speed, dive rate, climb rate, turn rate, inversion rate, firepower, durability, ceiling, operational range and general manoeuvrability of the aircraft. The MOF factor is a strong representation of the maximum speed, dive rate and climb rate attributes, while most of the other attributes are directly included in the various factors above. The aircraft's operational ceiling is considered below, which leaves turn rate, inversion rate and a measure of the overall manoeuvrability of the aircraft.

When considering manoeuvrability in air to air combat, and reviewing pilot discussions, the ability to out turn your opponent appears to be the most easily identifiable, measurable and critical parameter. However aircraft don't just execute turns; they need velocity to do so and they still need to be fast to rapidly attack or escape unwanted combat. For these reasons the turn rate and maximum level speed are both used to determine the aircraft's SpMvr factor. There is no direct measure of inversion rate but this is also tied directly to turn rate and speed. Note that some larger aircraft cannot invert fully at all and any inversion is more like a tight turn.

Once the aircraft's maximum turn time (measured in seconds to turn 360 degrees) and the maximum level speed (in kph) has been established, the SpMvr factor is determined using,

$$SpMvr_{Aircraft} = MaxSpeed * \left(1/\left(Turn\,Time\right)\right) * 0.33$$

The aircraft's maximum speed should be between 3 658 metres (12 000 feet) and 6 706 metres (22 000 feet) if possible. The maximum turn rate will occur at higher speeds and should be a turn of 360 degrees without inversion or change of altitude. Note, there are several manoeuvres to increase turn rate but they usually involve loss of altitude.

***

h. Ceiling Effect Factor (CL)

The CL factor is a measure of the aircraft's ability to utilise its operational ceiling for attack and defence purposes. It is considered an

offensive and defensive factor, and there is no directly similar factor in land based MFMs.

The operational ceiling, sometimes called service ceiling, is the maximum altitude the aircraft can normally operate with a normal load and without undue engine or airframe stress.

- For an aircraft with a maximum operational ceiling of 9,144 metres (30,000 feet), the CL factor is equal to 1.
- When the maximum operational ceiling is lower than 9,144 metres (30,000 feet), the CL value is reduced below 1 by 0.02 for every 305 metres (1,000 feet) below 9,144 metres.
- When the maximum operational ceiling is higher than 9,144 metres (30,000 feet), the CL value is increased above 1 by 0.005 for every 305 metres (1,000 feet) above 9,144 metres, up to 13,716 metres (45,000 feet). [260]
- When the maximum operational ceiling is higher than 13,716 metres (45,000 feet), the CL value is increased by 0.5 for every 305 metres (1,000 feet) above 13,716 metres.

For WWII aircraft a ceiling of around 10,000 metres, or lower, was normal. But there were exceptions. Probably the most famous one in 1941 was the Junkers Ju 86P-2 high altitude reconnaissance aircraft, capable of operating at up to 15,088 metres (49,500 feet). The Ju 86 was used extensively on deep reconnaissance missions over the Soviet Union prior to Operation Barbarossa. It first appeared over Britain in 1940 and subsequently over North Africa and the Mediterranean. In all cases it proved immune to interception due to its high altitude. The threat was eventually overcome by using stripped down Spitfires Vs, modified specifically to intercept the Ju-86s from mid-1942. The Ju 86 does however serve as an excellent example of the sometimes dramatic effect of the CL factor.

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[163] With the exception of Self-Propelled Artillery Factor (SPA) and Aircraft Mounted Weapon Effect (AE). Refer equations below for calculating an individual weapon's WCPC.

[164] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, p. 192. Note this data doesn't consider higher rates of fire from non-automatic AA weapons, e.g. 75-90mm AA guns.

[165] Some countries correctly refer to certain types of artillery (those restricted to firing at elevation angles from 45-90deg) as 'mortars'.

[166] The QJM model also uses cyclic rate per minute x4 for land based automatic weapons and x2 for air mounted automatic weapons. In addition QJM uses x2 for hand or shoulder weapons which is not used here. QJM does not consider any effects due to belt feed, water cooling, or dedicated MMG-HMGs crews over squad LMGs. T.N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, p. 191.

[167] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia 1985, p. 193.

[168] 'Muzzle velocity' denotes the velocity of the projectile at the moment it leaves the firing weapon's barrel (i.e. velocity at the muzzle).

[169] The RIE values used are based on historical experience. T.N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia 1985, pp. 20 and 26, and figs 2-3, pp. 188-191.

[170] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, pp. 21 and 191.

[171] There is variation in muzzle velocity and projectile mass depending on the ammunition used, which is dependent on the target. However this variation is relatively small, with the exception of 'special' AT ammunition. Thus it is assumed the muzzle velocity and projectile mass of APHE, APCBC, HE and AAHE rounds are similar. APDS, APCR and other special types of armour piercing shot have much higher muzzle velocities. But these rounds also have much less projectile mass, less range, are less accurate at longer ranges and were only available in limited numbers.

[172] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax Virginia, 1985, pp. 21 and 191. The constant 0.007 assures a value comparable to that of the formula based on range.

[173] Ibid, p. 194.

[174] Refer Volume I, Part II 2. 4) – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating an Aircraft's Overall Combat Power Coefficient (OCPC)'.

[175] Refer Volume I, Part II 2. 3) – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating a Land Based, Motorised Mobile Fighting Machine's (MFM's) Overall Combat Power Coefficient (OCPC)'.

[176] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia, 1985, p. 196.

[177] I. Gooderson, Allied Fighter-Bombers Versus German Armour in North-West Europe 1944-1945: Myths and Realities, Journal of Strategic Studies, Volume 14, Issue 2, June 1991, p. 212.

[178] Refer Volume I, Part II 2. 4) – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating an Aircraft's Overall Combat Power

Coefficient (OCPC)', and Volume I, Part II 3. 4) – 'Methodology for Calculating a Weapon System's or Database Unit's Specific Combat Attributes - Relative Anti-Armour Value (AT)'.

[179] German tanks in particular, were usually festooned with the necessary tools. They were attached to various parts of the tank or in metal lockers on the tank. These included jacks capable of lifting the tank, bolt cutters, hammers, wheel braces, spare track links and pins, etc. For most of WWII German Army tank crews were also generally trained to higher degree in basic tank repair and maintenance.

[180] The requirement that nearly all parts of an aircraft need to be operational for it to function effectively, is also a major reason why weak 'operational proficiency' in air forces results in much greater combat power degradation than in land forces. 'Operational proficiency' in air forces incorporates ground crews and support functions.

[181] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia 1985, p. 196.

[182] Ibid, pp. 27-29.

[183] Note for later. 'Typical Target Dispersion Factors (TDi)' is a major modification of the QJM. QJM does not consider variations in target dispersion due to weapon type, but applies a single 'Dispersion Factor' value to all weapon types.

[184] These 'Typical Target Dispersion Factors (TDi)' are a major modification of QJM. QJM does not consider variations in target dispersion due to weapon type, but applies a 'Dispersion Factor' value of 3 000 to all weapon types.

[185] The QJM model does not consider Tactical Responsiveness Factors (TRF), Fire Control Effects (FCE), Concealment and Protection Factors (CPF) and Defensive Dispersion Factors (DDF) for non-mobile weapons.

[186] Refer Volume I, Part II 2. 3) h. – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating a Land Based, Motorised Mobile Fighting Machine's (MFM's) Overall Combat Power Coefficient (OCPC) - Fire Control Effect (FCE)'.

[187] The QJM model does not consider Shape and Size Factor (SSF) and Open Top Factor (OTF), for mobile fighting machines. In addition the Battlefield Mobility Factor (MOF), Protection Factor (PR) and Fire Control Effect (FCE) are considerably simpler and calculated completely differently.

[188] Refer Volume I, Part II 2. 1) i. – 'Calculating individual Weapon Combat Power Coefficients (WCPCs) - Multi Barrelled Effect (MBE)'.

[189] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia 1985, p. 198. QJM uses the same method to calculate total APC weapons. In addition RFE, FCE and ASE factors for APCs are not included in APC calculations.

[190] Some Sd Kfz 251s also mounted another MG34 (or MG42 later in the war) at the rear, also on a swivel mount. The MGs could also be removed in action if required, or if the vehicle was disabled and the crew wanted to dismount with the MG.

[191] The QJM model uses 0.15 x the square root of the vehicle's road speed as the MOF factor.

[192] This type of vehicle already gets a benefit from the Range of Action (RA) factor, because they have longer road range.

[193] QJM uses weight to determine the PR factor, referred to as the Punishment Factor. QJM has no factors considering AFV shape and size. Generally this means that the QJM's PR factor is inaccurate. However by using the vehicle weight they avoid the even more inaccurate error of placing too much emphasis on the vehicle's front armour thickness and slope. Refer SSF factor entry for more on this.

[194] The *Panzerkamfwagen* IV Ausf H had 50mm front turret armour and 20-30mm side and rear armour.

[195] AFVs with heavier superstructure and turret armour generally also have a similar proportional increase in hull armour. Therefore the error introduced in the overall PR factor by not considering hull armour, is usually small because the change in most AFV's PR factor is relatively proportional. It should also be noted that in the SSF factor calculation below, the AFVs with steeply sloped turret and superstructure armour gain more benefit in their overall PR factor by ignoring hull armour because their armour is considered to be all sloped. However the vulnerable hull armour is almost always flat on the sides.

[196] Michael Wittmann with 138 tanks and 132 guns destroyed to his credit, mainly in a Tiger tank. G. Williamson, Aces of the Reich, Arms and Armour Press, London, 1989, p. 89.

[197] E. g. N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 59. Zetterling does point out that the Panther had superior mobility and its main gun had superior armour penetration at normal combat ranges. All other factors are, however, ignored, For example; the fact that the Tiger had a superior gun against all other target types and carried more ammunition, despite the Tiger's 88mm round being considerably bigger than the Panther's 75mm round.

[198] Data from: T.L. Jentz, Germany's Panther Tank: The Quest For Combat Supremacy, Schiffer Publishing Ltd, Atglen, PA, 1995, pp. 147 and 153. Also, the some of this data is presented in different form in P. Moore, Operation Goodwood: July 1944 A Corridor of Death, Helion & Company Ltd, Solihull, UK, 2007, Table IX, p. 176.

[199] P. Moore, Operation Goodwood: July 1944 A Corridor of Death, Helion & Company Ltd, Solihull, UK, 2007, Table XII, p. 177. The figures should be treated with some caution, especially as the type of AT weapons used is not shown. It is however reasonable to assume that, on average, the various German tank types came up against similar weapons.

[200] P. Moore, Operation Goodwood: July 1944 A Corridor of Death, Helion & Company Ltd, Solihull, UK, 2007, Table XV, p. 178. The sample used for this table is rather small (56 AP hits), but the trend is clear.

[201] Note, Tiger I production was 1354 and Tiger II production was 489, which leaves a total of 118 Tigers unaccounted for. Data compiled from: W. Schneider, Tigers in Combat I, JJ Fedorowicz Publishing Inc, Canada, 1994, and W. Schneider, Tigers in Combat II, JJ Fedorowicz Publishing Inc, Canada, 1998, and C. W. Wilbeck, Sledgehammers: Strength and Flaws of Tiger Tank Battalions in WWII, The Aberjona Press, Bedford, Pennsylvania, 2004, pp. 182-191.

[202] Detailed examination shows the Tiger I actually achieved a higher KR than the Tiger II. This was due to the strategic situation in 1945, which resulted in many Tiger IIs being abandoned or destroyed by their crews to prevent capture.

[203] Data from Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 406. Refer Appendix A, titled 'Armour Penetration Figures: Historical Test Results vs. Calculated Values' for more on calculating armour penetrations. Obviously the degree of apparent armour

increase due to a particular slope from vertical is the reciprocal of the armour penetration reduction value at the same degree of slope shown in Graph Pen vs Slope.

[204] The Commonwealth forces found this out when using 2 pounder AP shot in the early days of the North African campaign.

[205] There was also APBC ammunition which was an AP round with only a ballistic cap fitted. In addition there were a multitude of special ammunition types based around a hardened core, usually tungsten carbide. These ammunition types were always considered 'special' and supplied in limited numbers. They had much higher penetration, particularly at short to medium range. However they were less accurate and usually not used at longer ranges.

[206] Note this error may not be insignificant for low velocity weapons firing HEAT rounds, (High Explosive Anti-Tank) rounds. These are hollow charged weapons which are also affected by armour slope and angle of impact.

[207] ((2.41-2.11)/13) / ((1.96-1.82)/53) = 8.736.

[208] As an interesting aside, German assault gun commanders often complained their low silhouette vehicles were disadvantaged in Normandy in 1944 as they couldn't see over the hedgerows.

[209] For example, turret removal was common on Soviet tanks such as the T-34/85 and less common on the T-34/76 Model 1941/42. The T-34/85 had severe all-round turret overhang, particularly the front, as the original T-34 hull was designed for a much smaller two man turret with 76mm gun. The T-34/76 Model 1943 had a much improved and redesigned turret which removed the problem shot trap on earlier T-34's. The IS-2 and IS-2M also had severe front turret overhang, again due to the large turret and gun relative to the tank's superstructure and hull.

[210] For example, the Panther D and A had a round 100mm thick turret mantlet covering most of the turret front. The mantlet is so curved that any incoming rounds hitting below the barrel level are deflected through the superstructure roof, which is only 16mm thick, into the crew compartment. This weakness was well known to Sherman tank crews in Normandy in 1944, and they would aim for this area if faced with a Panther front on. In fact this weakness represents the only chance for a Sherman M4 with 75mm gun to penetrate a Panther frontally at any range. As the Panther's lower gun mantlet represents almost 50% of the turret front surface area, the Sherman crews had a reasonable chance of success. The Germans initially attempted to remedy the weakness by increasing superstructure armour under the turret front to 40mm on the Ausf G, produced from March 1944. However, only the addition of a redesigned and heavily armoured chin mantlet on some late war Panther Gs after September 1944, finally fixed the problem. It is also significant that the Panther F which never went into series production had a completely new *Schmal* turret. This had no curved mantlet at all, but reverted to a conical gun mantlet and a flat 120mm plate of armour sloped at 20 degrees from vertical.

[211] The later Panther Ausf G carried 81 rounds.

[212] P. Chamberlain, H. Doyle, T.L. Jentz, Encyclopedia of German Tanks of WWII, Arms and Armour Press, London, 1994, p. 64.

[213] On the T-34 the driver had a large hatch in front of his station, which constituted part of the tank's frontal sloped armour. The hatch constituted a minor shot trap and it was quite common for this hatch to be completely removed by a direct hit, probably wounding or killing the driver.

[214] Many WWII tanks did have a hatch in the floor. In the T-34 this was under the machine gunners station; difficult to get to at the best of times. However tank floor hatches are often bolted affairs which take some time to open, and are difficult or impossible to use if the terrain floor is rising between the tracks for whatever reason. It would take a very cool head to use this type of hatch if the tank caught fire and almost impossible if the hatch was bolted down.

[215] On the Pz III there were two hatches on the forward upper hull above the transmission. They were designed for maintenance access to the transmission, but the left most hatch (in front of the driver) doubles as an emergency escape hatch.

[216] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia, 1985, p. 24. The data is as used in the QJM model.

[217] The QJM model does not include a factor for separate warhead and charge in Mobile Fighting Machines (MFMs).

[218] The KV-2 also qualifies with separate ammunition. However the KV-2 had a crew of six so it could have had up to three loaders if needed in its excessively large turret. In this case normal RFE values apply.

[219] The Sturmpanzer IV was purely an assault weapon with a short 15cm L/12 howitzer, and never deliberately used to attack enemy tanks. The Soviet AFVs mentioned were all considered capable of engaging enemy armour as required, but their designs were not optimized for combat with enemy tanks.

[220] T. Bean, W. Fowler, Russian Tanks of WWII, Ian Allan Publishing, London, 2002, p. 134. The SU-152 and ISU-152 could fire two rounds per minute, under ideal conditions. The IS-2, ISU-122 had similar rates of fire.

[221] There are also unconfirmed reports that the 122mm D-25T Model 1943 gun on the IS series had to be lowered to a roughly horizontal position in order for the warhead and charge to be loaded. The gunner would then elevate the gun onto target after each round. However, the primary basis for this is that some German troops reported that the gun was lowered after each round. In late 1944 the Soviets introduced an improved breach for the 122mm D-25T gun. Among other things, this may have been to fix this problem.

[222] QJM only considers a judgemental FCE factor. There are no quantitative sub-factors considered.

[223] A classic example of the consistent and common underestimation of firepower is the example of the T-34/76 vs. the Sherman M4/75, and the T-34/85 vs. the Sherman M4/76. It is the norm in most books on these tanks to state that both versions of the T-34 were superior to both Sherman versions. This is based on the T-34 having better protection (armour and shape) and mobility. The firepower is considered similar on the earlier version because the 76mm gun on the T-34/76 was similar to the 75mm Sherman gun. The firepower on the T-34/85 is often considered superior, because its 85mm gun was larger than the 76mm Sherman gun. In addition, Soviet accounts are replete with their dismay at the ‘inferior’ Sherman tanks sent to them under lend lease. This view has become commonly accepted in the west as true. However, this view completely fails to address several realities:

Why was the kill/loss ratio of the same German tanks much higher in the German favour, when fighting T-34/76s and
T-34/85s than when fighting Sherman 75s and Sherman 76s? This was consistently the case even in

straight tank vs. tank combat without regard to other supporting arms, and taking into account relative unit combat proficiencies. In addition why did the T-34/85 score significantly less than a 1 to 1 kill/loss ratio in North Korea in direct tank vs. tank combat against the Sherman M4A3E8/76?

By 1945 no fewer than three out of nine Guards Mechanised Corps (the premier armoured units in the Red Army) were completely equipped with M4A2 Sherman tanks. One of them had even turned in all its T-34/85s to replace them with Shermans. The vast majority of 2 095 M4A2 Lend Lease Shermans with 76mm guns went into these units. Why did the Soviets give their best tank units 'inferior' Sherman tanks during WWII?

The answer to all three questions (above) lies in the respective tank's overall firepower and to a lesser extent their reliability. The T-34/76 had a terrible crew layout while the Sherman 75 had the classic three man turret. The Shermans also had superior optics, turret baskets, turret traverse systems, etc. In short, the Germans could almost always hit the T-34/76 much more often and without effective return fire, than when fighting against the Sherman 75. The T-34/85 finally gave the T-34 the three man turret. However the Sherman's 76mm gun had better penetration than the T-34/85's 85mm gun. Also the Sherman 76 retained markedly superior optics, better turret traverse systems and carried far more ammunition. In summary the T-34s did have superior protection and mobility, but the Shermans always had superior overall firepower. Of the three factors, it was firepower that most translated into combat performance.

Selected Refs: S. Zaloga, J. Kinnear, P Sarson, T-34-85 Medium Tank 1944-1994, Osprey Military, London 1996, pp. 36 and 37. C. Sharp, "Red Storm", Soviet Mechanised Corps and Guards Armoured Units 1942-1945: Volume III, George. F. Nafziger, West Chester, OH, 1995, pp. 10 and 11.

[224] 'Turret' in this regard includes the fighting compartments on fixed superstructure AFVs such as assault guns and some tank destroyers.

[225] To coordinate with other vehicles, WWII tanks mainly used radios, if available. However many countries did not have sufficient numbers or/and quality of radios, especially in the first half of the war. The Soviets were particularly plagued by this problem in 1941 and their tank commanders relied on flag signaling. The Soviets never had sufficient radios for all their tanks right up to war's end, despite large Lend Lease shipments. For calculation of FCE in the MFM, the presence or absence of radios is not factored in. This is because a radio is considered a <u>multi vehicle device</u> and is considered under tactical level combat proficiency (Refer Volume V). We are solely concerned here with the FCE of the individual vehicle. The focus here is on the tank commander's ability to fulfill the vehicle coordination role, by not being too busy fulfilling other roles during combat. Note, if the tank lacked any form of internal communication device (intercom) between crew members, then this would have a direct detrimental effect on any FCE factor.

[226] All saw service in the German Army after 1940. They were designated *Panzerkampfwagen* 35R 731(f), *Panzerkampfwagen* 38H 735(f), and *Panzerkampfwagen* 35-S 739(f). The latter two types saw service with the 211th *Panzerabteilung* in June 1941 on the Finnish/Soviet border.

[227] It is worth noting that the Soviet light tanks T-40 Model 1940 with 12.7mm or 20mm cannon, T-60 Model 1941 with 20mm cannon and T-70 Model 1942 with 45mm gun, all had one man turrets. This is surprising; especially in the T-70 which was produced well after one man turrets were seen to be so ineffective. The T-40, T-60 and T-70 kill/loss results were, accordingly, terrible.

[228] The KV-1 had a three man turret. However the commander doubled as the gun loader. The third man worked the rear turret MG and was the assistant driver mechanic. This position was needed to help the driver because of his very heavy workload due to the poor clutch, transmission and steering

design. Refer Volume IIIA, 2. 6) m. – ‘The Soviet Personnel and Equipment Resource Database - Tanks - KV-1 Heavy Tanks’, for more on KV tank crew functions.

[229] The B-1 and B-1 bis had an additional hull mounted 75mm gun in front and only a crew of four. Presumably the loader doubled for both main guns. If the loader was preoccupied with the larger hull mounted gun, the turret operated as a one man turret.

[230] P, Chamberlain, H Doyle, T Jentz, Encyclopedia of German Tanks of WWII, Arms and Armour Press, London, 1994, p. 43.

[231] S. Zaloga, J. Kinnear, P Sarson, T-34-85 Medium Tank 1944-1994, Osprey Military, Reed International Books Ltd, London, 1996, p. 7.

[232] Firing tests revealed that the average calm gunner in a Tiger I, after sensing the tracer from the first round, had a 50%, 31% and 19% chance of hitting a target 2 meters high and 2.5 meters wide, at 2 000, 2 500 and 3 000 meters, respectively (on the second round), using standard Pzgr.39 shot. Under practise conditions where the range was already accurately determined, the figures were 87%, 71% and 53%. T.L.Jentz, Germany’s Tiger Tanks: Tiger I & II Combat Tactics, Schiffer Publishing Ltd, Atglen, PA, 1997, p. 10.

[233] J. Norris, M. Fuller, 88mm FlaK 18/36/37/41 & PaK 43 1936-45, New Vanguard, Osprey Publishing Ltd, Oxford, 2002, p. 7.

[234] T. L. Jentz, Germany’s Panther Tank: The Quest For Combat Supremacy, Schiffer Publishing Ltd, Atglen, PA, 1995, p. 126.

[235] P. Chamberlain, H. Doyle, T.L. Jentz, Encyclopedia of German Tanks of WWII, Arms and Armour Press, London, 1994, p. 64.

[236] On Pz IIIs and IVs the commander’s hatch was usually a small single piece hatch which lifted upwards to the side and rear of the turret. Some tanks had small two piece hatches. On later war tanks, such as the Tiger and Panther, the commander’s hatch design was improved: it lifted slightly and then rotated horizontally around a circular pivot.

[237] S. Zaloga, J. Kinnear, P. Sarson, T-34-85 Medium Tank 1944-1994, Osprey Military (Reed International Books Ltd), London, 1996.

[238] S. J. Zaloga, J Kinnear , P. Sarson, KV-1 & 2 Heavy Tanks 1941-1945, Osprey Military, Reed International Books Ltd, London, 1995, pp. 24 and 33. A German report on the KV-1 stated the Soviet vision devices were poor, the armoured glass was sub-standard being full of air bubbles and “Facilities for observation are worse than in our tanks. The driver’s vision is incredibly bad”.

[239] The T-34 Model 1943 incorporated an improved turret which had less sloped armour, more internal room (but still only two crewmembers), and usually two small circular hatches. Some of the later T-34 Model 1943s had a circular vision cupola added to the turret roof over one of the hatches (in the German pattern).

[240] Data from S. Zaloga , P. Sarson, T-34/76 Medium Tank 1941-1945, Osprey Military, Reed International Books Ltd, London 1994, pp. 38-39. Also T. Bean, W. Fowler, Russian Tanks of WWII, Ian Allan Publishing, London, 2002, pp. 86-87.

[241] B. Perrett, J. Laurier, Panzerkampfwagen IV Medium Tank 1936-1945, Osprey Publishing Ltd, Oxford, 1999, p. 19.

[242] Quote, S. Zaloga , P. Sarson, T-34/76 Medium Tank 1941-1945, Osprey Military, Reed International Books Ltd, London, 1994, p. 40.

[243] Ibid, p. 40.

[244] Ibid, p. 12.

[245] Refer Volume IIIA, 2. 6) k. i. – 'The Soviet Personnel and Equipment Resource Database – Tanks - T-34 Medium Tanks - The T34 in WWII: the Legend vs. the Performance', for more on the combat performance of the T-34 from 1941-45.

[246] Examples during 1941 are the 15cm sIG33(Sf) auf Panzerkampfwagen I Ausf B, 2cm FlaK auf Fahrgestell Zugkraftwagen 1t (Sd Kfz 10/4), and 8.8cm FlaK18(Sfl) auf Zugkraftwagen 12t (Sd Kfz 8).

[247] In addition, armoured trains and APCs are considered to have an ASE factor = 1.

[248] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia, 1985, p. 25. The data is as used in the QJM model.

[249] T. N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia 1985, p. 197.

[250] The QJM model does not consider any Durability Factor (DUR), Shape and Size Factor (SSF), and Maximum speed and Manoeuvrability Factor (SpMvr) for aircraft. In addition the Battlefield Mobility Factor (MOF) is calculated completely differently.

[251] The Maximum speed and Manoeuvrability Factor (SpMvr) is arguably an offensive factor especially in fighters and fighter-bombers. However aircraft mobility in offence is already considered in the Battlefield Mobility Factor (MOF) and non-fighter/fighter bombers use their SpMvr factors to avoid damage, i.e. defensive in nature. Experimentation showed that including SpMvr as an offensive factor had little effect on aircraft OCPCs.

[252] Refer Volume I, Part II 2. 1) h. – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating individual Weapon Combat Power Coefficients (WCPCs) - Aircraft Mounted Weapon Effect (AE)'.

[253] Refer Volume I, Part II 2. 1) i. – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating individual Weapon Combat Power Coefficients (WCPCs) - Multi Barrelled Effect (MBE)'.

[254] Note, for aircraft the type of mounting affects the accuracy rating of aircraft mounted weapons (which in turn affects the particular weapon's WCPC value). Refer Volume I, Part II 2. 1) e – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating individual Weapon Combat Power Coefficients (WCPCs) - Accuracy (A)'.

[255] The QJM model uses 0.15 x the square root of the aircraft's maximum air speed as the MOF factor. For aircraft the MOF factor is modified to take into account that optimum ground attack speeds are much less than maximum air speeds. This effect is very small for WWII aircraft (even the few with ground attack speeds above 500 km per hour), but significant for modern jet fighter bombers which would have great difficulty attacking ground targets at supersonic speeds. T.N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia 1985, pp. 196-197. Note the

maximum air speed is still used in calculating the Maximum speed and Manoeuvrability Factor (SpMvr), (refer below).

[256] The turn rate is still used in calculating the Maximum speed and Manoeuvrability Factor (SpMvr), (refer below).

[257] The lack of self-sealing tanks was one of the biggest weaknesses in the Mitsubishi A6M 'Zero' fighter. This, coupled with the light airframe, gave these aircraft a very low durability factor. In addition the Mitsubishi G4M 'Betty', the most produced Japanese bomber of WWII, became known as the 'Flying Lighter' due to its propensity to burst into flames. It should be noted, however, that both these aircraft enjoyed the benefits of having exceptional range, so it is apparent their designers sacrificed crew and fuel protection in order to cram in as much fuel as possible.

[258] The Tupolev SB-2, SB-2bis, and early model Ilyushin DB-3 definitely lacked fuel protection. The improved DB-3F featured some fuel protection, and production of this model commenced in 1939/40.

[259] The one exception to this is the Tupolev SB-2 and SB-2bis. The most common Soviet bomber available in June 1941, the Tupolev SB-2 and SB-2bis did not have any fuel protection. German fighter pilots soon learned a few bullets into the fuel tank of these aircraft usually resulted in fire and total aircraft destruction. C. Bergstrom, A. Mikhailov, Black Cross Red Star, Pacifica Military History, Pacifica, California, 2000, p. 44. For this reason the DUR factor on these aircraft is reduced by 1.

[260] The CL factor up to 45 000 feet is as per QJM. T.N. Dupuy, Numbers, Predictions and War, Hero Books, Fairfax, Virginia, 1985, p. 198.

3. Methodology for Calculating a Weapon System's or Database Unit's Specific Combat Attributes

Up till now we have been concerned with calculating the Overall Combat Power Coefficients (OCPCs) of the various weapon systems and small units. The OCPC value is very useful in evaluating the overall lethality of weapons and for calculating parameters such as relative combat proficiency. [261] However the OCPC value in its pure form is not directly useful to designers of military simulations or war games. What they require is more tangible and refined values for specific combat attributes, such as a weapon system's anti-tank or anti-aircraft capability.

Fortunately the structure of the OCPC methodology, and the many attributes already researched and calculated, easily lend themselves to calculating these specific combat attributes. We are now in a position to calculate the following specific attributes relating to non-mobile weapon systems or squads, land based motorised Mobile Fighting Machines (MFMs), and aircraft.

- Relative Overall Attack Factor (ATT).
- Relative Overall Defence Factor (DEF).
- Effective Combat Ranges (R) and Aircraft Combat Radius (R)
- Relative Anti-Personnel Value (APer).
- Relative Anti-Armour Value (AT).
- Relative Anti-Aircraft Value (AA).
- Relative Fortification Destruction Effect (FDE).
- Relative Armour Defence Strength (ARM) for land based motorised Mobile Fighting Machines (MFMs).

- Relative Assault Defence Strength (ADS) for non-mobile weapon systems or squads, and land based motorised Mobile Fighting Machines (MFMs).
- Relative Assault Attack Strength (AAS) for non-mobile weapon systems or squads, and land based motorised Mobile Fighting Machines (MFMs).
- Relative Overall Mobility (MOB).
- Supply Demand Factor (SDF).

The weapon system or squad attributes listed above (except SDF) constitute the most common types used in most military simulations. These values (along with values representing other parameters such as weather, readiness, supply state, terrain, fortification level, and tactical and operational combat proficiency) are used directly in the combat model 'engine' to resolve combat between opposing forces.

***

1) Relative Overall Attack Factor (ATT) and Relative Overall Defence Factor (DEF)

In some military simulations, one value is used to represent the total attack or defence capability of a given weapon system or a small infantry unit (one or more squads). We therefore require a way of extracting this from our OCPC methodology.

Within each of the weapon type OCPC methodologies, the various factors considered were classified as offensive, defensive, or both offensive and defensive. In addition to some minor adjustments, the ATT factor is equal to the product of all the offensive factors, and factors which are both offensive and defensive. Similarly, the DEF factor is equal to the product of all defensive factors, and factors which are both offensive and defensive.

For non-mobile weapon systems or squads , the Overall Combat Power Coefficient, (OCPC) is given by,

$$OCPC_{Non\ Mobile\ Wpn\ Sys\ or\ Squad} = \left(\sum_{1}^{x} WCPC_x * TRF * FCE \right) + \left(CPF * DDF \right)$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all weapons in the squad (x = all weapons), or the WCPC, of the primary weapon in a non-mobile weapon system (x =1). As defined previously, the factors on the left side of the plus sign in the equation are essentially offensive factors while those on the right are essentially defensive factors. Thus for non-mobile weapon systems or squads.

$$ATT_{Non\ Mobile\ Wpn\ Sys\ or\ Squad} = \left(\sum_{1}^{x} WCPC_x * TRF * FCE \right) / 5$$

$$DEF_{Non\ Mobile\ Wpn\ Sys\ or\ Squad} = 1 + \left(\left(CPF * DDF \right) / 5 \right)$$

The constant 5 is simply to reduce the large OCPC number to a more manageable value which is numerically similar to values used in most military simulations. The constant 5 will be used in all the relevant equations below for this conversion. The number 1 (added to the DEF factor) is there because, no matter what, the overall defensive value of a weapon system or squad is never zero, but may drop as low as 1.

***

For MFMs the Overall Combat Power Coefficient (OCPC) is given by,

$$OCPC_{MFM} = \left(\left(\sum_{1}^{MBE} WCPC_{MFM} * MOF * RA \right) + \left(PR * SSF * OTF \right) \right) * RFE * FCE * ASE * WHT$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all LMGs and larger weapons on the Mobile Fighting Machine (MFM), added up using modified Multi Barrel Effect (MBE) rules.

As defined previously, the factors WCPC, MOF and RA are essentially offensive components while PR, SSF and OTF are essentially defensive components. Factors RFE, FCE, ASE and WHT are both offensive and defensive factors. Thus for MFMs,

$$ATT_{MFM} = \left(\sum_{1}^{MBE} WCPC_{MFM} * MOF * RA * RFE * FCE * ASE * WHT\right)/5$$

$$DEF_{MFM} = 1 + \left(\left(PR * SSF * OTF * RFE * FCE * ASE * WHT\right)/5\right)$$

***

For aircraft the Overall Combat Power Coefficient (OCPC) is given by,

$$OCPC_{Aircraft} = \left(\left(\sum_{1}^{MBE + Air\ L\ Wpns} WCPC_{Aircraft} * MOF * RA\right) + \left(DUR * SSF * SpMvr\right)\right) * CL$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all aircraft mounted weapons on the aircraft, added up using modified Multi Barrel Effect (MBE) rules, and the simple sum of WCPCs for all aircraft launched weapons (bombs and rockets). As defined previously, the factors WCPC, MOF and RA are essentially offensive factors while DUR, SSF and SpMvr are essentially defensive factors. The CL factor is both an offensive and defensive factor. Thus for aircraft,

$$ATT_{Aircraft} = \left(\sum_{1}^{MBE + Air\ L\ Wpns} WCPC_{Aircraft} * MOF * RA * CL\right)/5$$

$$DEF_{Aircraft} = 1 + \left(\left(DUR * SSF * SpMvr * CL\right)/5\right)$$

Note, fighter-bombers should have their Relative Overall Defence Factor (DEF) (and Relative Anti-Aircraft Value (AA), refer below) reduced by approximately 1 when executing ground attack sorties with bombs and rockets. This is due to loss of manoeuvrability, speed and range, while carrying heavy ordnance. Obviously jettisoning the bombs removes the problem, but results in a failed primary mission and the equations assume aircraft execute their primary mission.

***

This, however, is not the end of the ATT and DEF story. The problem with the rigid application of formulas in calculating the ATT and DEF

values is the assumption that certain factors are strictly offensive and others are strictly defensive. This is why the term ‘essentially’ offensive and defensive is used, and why certain factors are classified as both offensive and defensive. As we have seen with the aircraft SpMvr factor, a factor may be considered defensive but it may arguably also be an offensive factor.

There are many similar examples, such as the PR and WCPC factors in MFMs. In this case a tank with strong armour (a higher PR value) is obviously more powerful defensively, but it can also be considered more powerful in attack because its armour enables it to survive longer and hence inflict more damage while attacking. This means the tank’s PR factor has a direct effect on its ATT value. Similarly, a tank with weak armour and a more powerful main gun (a higher WCPC value) is obviously more powerful offensively, but it can also be considered more powerful in defence because its gun will destroy an attacking enemy more rapidly. This means the tank’s WCPC factor has a direct effect on its DEF value.

This grey area stems from the nature of combat and weapons systems. In reality a weapon system with strong defensive characteristics is often stronger on the attack, and vice versa. The degree to which the defensive characteristics of a weapon system can reasonably be ‘converted’ to attack type characteristics, and vice versa, is dependent on the specific weapon system. However the parameter that does not readily change in the debate above is the Overall Combat Power Coefficient (OCPC) of the weapon system or squad, because it incorporates <u>all</u> the defensive and offensive components. [262]

Therefore, at all times the following equation must hold true for all types of weapon system or squad.

$$OCPC_{All\ types\ Wpn\ Sys\ or\ Sqd} = \left(ATT_{All\ types\ Wpn\ Sys\ or\ Sqd} + \left(DEF_{All\ types\ Wpn\ Sys\ or\ Sqd} - 1\right)\right) * 5$$

Note, the constant 5 was introduced simply to reduce the large OCPC number to values compatible with most military simulations. Also the number 1 was added to ensure the DEF value is never fully zero.

If the ATT and DEF values are mutually adjusted for a specific weapon system or squad, to take account of any changes in the offensive or defensive nature of the factors being considered, then equation above must remain valid at all times.

***

2) Effective Combat Ranges (R) and Aircraft Combat Radius (R)

Combat ranges used in military simulations are a function of the physical limitations of the weapon system and the principal mission assigned to the weapon system type.

Although many weapon systems can reach targets at long distances, they are not normally asked to do so. For example, anti-tank (AT) guns are usually used at ranges which allow line of site targeting: i.e. they are usually used in direct fire mode. In general these weapons have high muzzle velocities and could fire considerably further if they were tasked with firing in indirect fire mode and with angles of fire of around 45 degrees. However, they are not designed for this and are rarely used in this role. Their combat power is not normally exerted over these ranges, and these ranges are not used in calculating the AT gun's OCPC values. Thus the range of these types of guns is normally limited to direct fire ranges, which is what they can see horizontally on reasonably flat terrain. [263] For our purposes we are interested in the range (R) over which the majority of the combat power of the weapon system is normally applied . This is the termed the Effective Combat Range (R). (Note, R refers to horizontal range and this is different to the Effective Ceiling (CLR) used in calculating the Relative Anti-Aircraft Value (AA), refer entry below).

For these reasons we will separate combat ranges as follows:

- **Direct Fire Effective Combat Range (R)** for direct fire weapons and squads.
- **Indirect Fire Effective Combat Range (R)** for indirect fire weapons.

- **Combat Radius (R)** for aircraft.
- **Direct Fire weapons and squads** include light infantry weapons, light infantry weapon equipped squads, heavy infantry weapons (including mortars,[264] infantry guns and AT guns), AA guns firing at land targets,[265] and MFMs.[266] For these weapons the Effective Combat Range (R) is never more than 3kms.
- **Indirect Fire** weapons include all types of artillery and rocket artillery.
- **Aircraft** includes all types of aircraft.

Most weapon systems have a maximum combat range specified. This is normally the maximum range at which the weapon system will have any effect and is a function of many parameters including muzzle velocity, optics, ammunition design and carriage design. However the maximum combat range of a weapon is not the same as its Effective Combat Range (R). Although a weapon system can reach a long way it will not be able to exert most of its lethality over that distance.

For example, the 88mm Flak 18/36 could fire at and reach land targets, in direct fire mode, over 3000 metres away. But even with its excellent optics and fire control the large majority of rounds would miss. At 1500-2000 metres, however, the same weapon would be at least twice as lethal. In this case the maximum combat range would be around 3000 metres, which means it still has a significant destructive effect but it's borderline whether firing is worth the ammunition expenditure and gun wear. The Effective Combat Range (R) is therefore around 2000 metres because at this range the '88' can exert the 'majority of its combat power' and the crew would not normally hesitate to do so.

For calculating Effective Combat Range (R) and Aircraft Combat Radius (R) we therefore use the following,

$$R_{Light\ Infantry\ Wpns} = Roundup\left(Max\ Combat\ Range_{Light\ Infantry\ Wpns} * 0.3\right)$$

$$R_{Heavy\ Infantry\ Wpns,\ AA\ guns,\ MFMs} = Roundup\left(Max\ Combat\ Range_{Heavy\ Infantry\ Wpns,\ AA\ guns,\ MFMs} * 0.5\right)$$

$$R_{Artillery\ and\ Rocket\ Artillery} = Roundup\left(Max\ Combat\ Range_{Artillery\ and\ Rocket\ Artillery} * 0.9\right)$$

$$R_{Aircraft} = Roundup\left(\left(Normal\ Range_{Aircraft} / 2\right) * 0.8\right)$$

A proviso for the above equations is that for direct fire weapons the *Max Combat Range* is never more than 3kms (3000m). All R factors are rounded up to the nearest whole number in the accompanying tables in this work (refer Volumes II, III and IV).

'Normal range' for aircraft is the same as defined for calculating the aircraft's RA factor.

***

3) Relative Anti-Personnel Value (APer)

In more sophisticated military simulations, one value is usually used to represent a weapon system's or squad's attack value against non-armoured or 'soft targets'. This is termed the Relative Anti-Personnel Value (APer) value. Soft targets are susceptible to near misses by high explosive rounds, and are often dispersed or in entrenched locations. Soft targets include personnel, all types of non-armoured vehicles and all types of non-armoured weapon systems. All targets with a Relative Armour Defence Strength (ARM) less than 1 are considered to be soft targets (refer ARM entry below).

The whole OCPC methodology is based around the lethality of the weapon system to enemy personnel. As defined previously, the lethality of the weapon or database unit is defined as 'the inherent capability of a given weapon or unit to kill personnel, or to make material ineffective in a given time period'. In Part II 2., detailing the methodology for calculating individual Weapon Combat Power Coefficients (WCPCs), we considered several factors influencing the weapon's lethality to personnel and other soft targets. In particular, Number of Potential Targets per Strike (PTS),

Relative Incapacitating Effect (RIE), and Typical Target Dispersion Factor (TDi) were all factors mostly concerned with dispersed personnel type targets. For this reason we can extract the APer value directly from our OCPC methodology.

Essentially we need to measure the relative anti-personnel value of a weapon system or squad firing in a stationary mode against soft targets for the period of one hour. One hour is used as this is the time period specified in the WCPC Rate of Fire (RF) factor. The Relative Anti-Personnel Value (APer) is therefore purely an offensive value used for attacking soft targets. Thus we will only use offensive factors, and factors which are both offensive and defensive. In addition we can also remove factors related to battlefield mobility or operational range.

For non-mobile weapon systems or squads , **except AT weapons**, the Relative Anti-Personnel Value (APer) is given by,

$$APer_{Non\ Mobile\ Wpn\ Sys\ or\ Squad} = Roundup\left(\left(\sum_{1}^{x} WCPC_{x} * TRF * FCE\right)/5\right)$$

where Roundup means rounded up to the nearest whole number (and will be used in all the equations below), and the (capital sigma) WCPC summation is the sum of WCPCs for all weapons in the squad (x = all weapons), or the WCPC of the primary weapon in a non-mobile weapon system (x =1).

There are two provisos in using the above equation which are,

- For AT weapons, including anti-tank guns and AT rifles, the APer value calculated above <u>is halved</u>. This is to take into account that these weapons fire mainly Armour Piercing (AP) type ammunition and relatively little High Explosive (HE) ammunition.
- A weapon system crew or squad, with no LMG or larger gun, must have at least 5 Rifles or 5 SMGs to have an APer value greater than zero.

***

For MFMs the Relative Anti-Personnel Value (APer) is given by,

$$APer_{MFM} = Roundup\left(\left(\sum_{1}^{MBE} WCPC_{MFM} * RFE * FCE * ASE\right)/5\right)$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all LMGs and larger weapons on the Mobile Fighting Machine (MFM), added up using modified Multi Barrel Effect (MBE) rules.

There is one proviso in using the above equation which is,

- Vehicles with no LMG or larger gun can include crew-manned small arms, but they must have a crew with at least 5 rifles or 5 SMGs to have an APer value greater than zero.

***

For aircraft the Relative Anti-Personnel Value (APer) is given by,

$$APer_{Aircraft} = Roundup\left(\left(\sum_{1}^{MBE + Air\ LWpns} WCPC_{Aircraft}\right)/5\right)$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all aircraft mounted weapons on the aircraft, added up using modified Multi Barrel Effect (MBE) rules, and the simple sum of WCPCs for all aircraft launched weapons (bombs and rockets).

***

4) Relative Anti-Armour Value (AT)

Similarly to the APer value above, most sophisticated military simulations use a separate value to represent a weapon system's or squad's attack value against Armoured Fighting Vehicles (AFVs); often termed

‘hard targets’. This is termed the Relative Anti-Armour or Anti-Tank (AT) value.

Armoured or hard targets are usually less dispersed compared to soft targets due to their physical nature, but are much less susceptible to near misses or even direct hits by high explosive rounds. Hard targets are aptly named because heavily armoured vehicles usually require a direct hit with a suitably powerful AT weapon to destroy them. All targets with a Relative Armour Defence Strength (ARM) greater than or equal to 1, are considered to be hard targets (refer ARM entry below).

As discussed previously, the OCPC methodology is principally based around the lethality of the weapon system to enemy personnel. However the OCPC methodology does contain factors pertaining to AT performance. In Part II 2., detailing the methodology for calculating individual Weapon Combat Power Coefficients (WCPCs), the main factors relevant to AT performance were the Rate of Fire (RF), Range (RN), Accuracy (A) and Aircraft Mounted Weapon Effect (AE) factors. Of these, the RN factor considers muzzle velocity which is directly related to AT capability.

On balance however, the WCPC part of the OCPC methodology does not give an accurate enough measure of a weapon system’s ability to penetrate armour at specific ranges, which we need to measure a weapon system’s true Relative Anti-Armour Value (AT). We therefore need additional external information that has not yet been researched for the OCPC methodology so far.

***

a. Relative Anti-Armour Value (AT) for Land Based Weapon Systems and Squads

The additional information required to calculate AT is a direct measure of the weapon system’s ability to penetrate armour. We will specifically use the penetration of homogeneous armour plate sloped at 30 degrees from vertical at 1000 metres range, and using the weapon system’s most common type of AT round.

Using the most commonly available AT round is very important because AT performance varies greatly with ammunition type used. As we are trying to calculate the average AT value for a weapon system, then on average it will be using the most common round produced for that weapon. This is usually AP, APC or APCBC. Also the armour quality and any 'face hardening' used in different AFVs are not considered directly here. This includes the overall 'hardness' and 'brittleness' of the armour (measured in Poldi or Brinell No units), which can have a very significant effect on an AFV's armour protection. This is one of the factors to consider in deciding on whether to use historical test results or calculated values for armour penetration figures. Refer to Appendix A for more information on determining armour penetration figures from historical test results and calculated values. [269]

For land based weapon systems and squads (as opposed to aircraft) other parts of the OCPC methodology, outside the WCPC calculation, have a direct impact on any weapon system's or squad's AT value. For land based weapon systems and squads the factors brought into play here are Rapidity of Fire Effect (RFE), Fire Control Effect (FCE), Ammunition Supply Effect (ASE) and Tactical Responsiveness Factor (TRF). Some of these factors are at least as important as the penetrative abilities of the weapon system being considered.

As for the APer value, we need to measure the relative anti-armour value of a weapon system or squad firing in a stationary mode against hard targets. The Relative Anti-Armour Value (AT) is therefore purely an offensive value used for attacking hard targets. Thus we will only use offensive factors, and factors which are both offensive and defensive. We can also remove factors related to battlefield mobility or operational range.

For non-mobile weapon systems or squads the Relative Anti-Armour Value (AT) is given by,

$$AT_{Non\ Mobile\ Wpn\ Sys\ or\ Squad} = Roundup\left(\left(PEN_{30\,\mathrm{deg}/\,1000\,m} * TRF * FCE\right)/\,5\right)$$

where $PEN_{30deg/1000m}$ is the ability of the most powerful AT weapon in the weapon system or squad to penetrate homogeneous armour plate sloped

at 30 degrees from vertical at 1000 metres range, using its most common AT round. [270] Refer to Appendix A for a more on determining armour penetration figures from historical test results and calculated values.

There are two important provisos in using the above equation as follows.

- A weapon system crew or squad, with no LMG or larger gun, must have at least 5 Rifles or 5 SMGs to have an AT value greater than zero.
- The OCPC and hence AT calculated for artillery, is for indirect fire only. If forced to use artillery in direct fire against armour, the AT value is calculated as 0.33 times its Relative Overall Attack Factor (ATT), provided APHE (Armour Piercing High Explosive) or HEAT (High Explosive Anti-Tank) rounds were developed and are available for the weapon. If this ammunition was not available (which is likely) then the equation above is used with very low penetration values for HE rounds.

***

It is important to understand here that the AT value for an infantry squad is not its ability to kill armour by close assaulting it. This is discussed later under the section on calculating Relative Assault Attack Strength (AAS) and Relative Assault Defence Strengths (ADS) below. The AT value is purely the ability to kill armour by simply shooting at it. One might then ask why this is not zero for squads only equipped with small arms and no AT rifles, as they would have little effect on armour by simply shooting at it?

The best way to answer this is to look at the AT performance of typical small arms ammunition. As an example let us examine the German standard issue rifle in WWII. The most common German small arms weapon in WWII was the 7.92mm *Karabiner* 98K (7.92mm bolt action rifle). Common ammunition manufactured and issued for this weapon (also used for the MG 34 and MG 42 squad LMGs) was the *Infanteriepatrone* cartridge (7.92x57mm Mauser cartridge) and *schweres Spitzgeschoss* (heavy pointed bullet). When fired from the 98K it had a muzzle velocity of

around 755m/s and could penetrate 5mm and 3mm of steel at 100 and 600 metres respectively, and 10mm and 7mm of iron at 300 and 550 metres respectively. This is a significant anti-armour performance against many light AFVs (such as light armoured cars), and is the reason why many small rifle equipped squads don't have an AT value of zero.

***

For MFMs the Relative Anti-Armour Value (AT) is given by,

$$AT_{MFM} = Roundup\left(\left(PEN_{30\deg/1000m} * RFE * FCE * ASE\right)/5\right)$$

where $PEN_{30deg/1000m}$ is the penetration ability of the most powerful AT weapon on the MFM to penetrate homogeneous armour plate sloped at 30 degrees from vertical at 1 000 metres range, using its most common AT round. Refer to Appendix A for a more on determining armour penetration figures from historical test results and calculated values.

There is one proviso in using the above equation which is,

- Vehicles with no LMG or larger gun can include crew-manned small arms, but they must have a crew with at least 5 rifles or 5 SMGs to have an AT value greater than zero.

***

b. Relative Anti-Armour Value (AT) for Aircraft

For aircraft (as opposed to land based weapon systems and squads) the parts of the OCPC methodology which are outside the WCPC calculation, do not have a direct impact on the aircraft's AT value. For aircraft the relevant AT factors are contained in the individual aircraft's Weapon Combat Power Coefficient (WCPC) calculation: specifically the Accuracy (A) and Aircraft Mounted Weapon Effect (AE) factors. For aircraft these factors are far more important than the penetrative abilities of the weapon system being considered. Refer to Appendix B for more on the problems that WWII era aircraft faced when attacking armour during WWII.

As for the aircraft APer value, we need to measure the relative anti-armour value of an aircraft flying a single mission against hard targets. For aircraft the AT value is dependent on the strongest AT weapon carried. This could be either the aircraft's mounted weapons (cannons, MGs or light AT gun) or air launched weapons (rockets or bombs).

For aircraft with stronger aircraft mounted AT weapons , the Relative Anti-Armour Value (AT) is given by,

$$AT_{Aircraft} = Roundup\left(\left(PEN_{30\deg/1000m} * 3 * A * AE\right)/5\right)$$

where: $PEN_{30deg/1000m}$ is the penetration ability of the most powerful aircraft mounted weapon. The penetrative ability of the aircraft's weapons in this case is multiplied by 3 to take into account that a large proportion of hits against AFVs will be hitting the thinner top armour. Top armour would be around a third as strong as frontal and side armour on the average AFV.

A is the Accuracy (A) factor and AE is the Aircraft Mounted Weapon Effect (AE) factor used in calculating the WCPC for the aircraft mounted weapon being considered.

***

For aircraft with stronger aircraft launched AT weapons , the Relative Anti-Armour Value (AT) is given by,

$$AT_{Aircraft} = Roundup\left(\left(PEN_{Air\ L\ Wpns} * A * AE\right)/5\right)$$

where: $PEN_{Air\ L\ Wpns}$ is the penetration ability of the most powerful aircraft launched weapon carried, deduced from the table below.

Air Launched Weapon vs. Equivalent Anti-Armour Performance			
Air launched rockets, by year of service	Air launched, free-fall bomb weight, kg	Equivalent armour penetration, mm	Radius of bomb PTS area, m
	10	5	21
1940	50	10	37
1941	100	20	44
1942-1943	250	30	47
1944-1945	500+	40	50+

A is the Accuracy (A) factor and AE is the Aircraft Mounted Weapon Effect (AE) factor used in calculating the WCPC for the aircraft launched weapon being considered. Note, for aircraft launched weapons, the AE factor is normally (but not always) = 1.

Refer to Appendix B for more on the effectiveness of combat aircraft against armour in WWII and further discussion on the values used to calculate for air launched weapon systems.

***

5) Relative Anti-Aircraft Value (AA)

Similarly to the APer and AT values above, most military simulations use one value to represent a weapon system's or squad's attack value against aircraft. This is termed the Relative Anti-Aircraft Value (AA) value.

Aircraft are classified as 'soft targets' because they are susceptible to near misses by high explosive rounds and small arms fire. Any armour protection carried is usually thin, dispersed and still vulnerable to cannon and MG fire. We know that the OCPC methodology is principally based around the lethality of weapon systems to soft targets, particularly enemy personnel. Hence we are able to use the weapon system's WCPC values as the starting point of our AA calculation (unlike the AT value calculated above).

The big change here is that most weapon systems are not able to use their primary weapon against aircraft. Most weapon systems are not able to elevate, track and sight aircraft with their primary weapon, and have no suitable anti-aircraft ammunition. These weapons include heavy infantry weapons, artillery, rocket artillery and most types of land based Motorised Mobile Fighting Machine (MFMs). Weapon systems capable of attacking aircraft with their primary weapon include other aircraft, light infantry weapons (except grenades, rifle grenades, flamethrowers and demolition charges), light infantry weapon equipped squads, AA guns and MFMs with mounted AA guns. However, most weapon systems and squads are able to use their secondary weapons to defend against aircraft. These include LMGs (such as those found in squads and mounted on AFVs), HMGs and most types of small arms with the crew manning the primary weapon system.

***

a. Relative Anti-Aircraft Value (AA) for Land Based Weapon Systems and Squads

Apart from determining if the weapon can be used against aircraft, the two most critical factors in determining overall AA capabilities for land based weapon systems are fire control and the height (or ceiling) the gun can effectively reach. For this purpose we can use the Fire Control Effect (FCE) factor used in calculating the weapon system's OCPC. [271] For ceiling we are interested in the maximum height over which the majority of the combat power of the weapon system can be applied. This is the Effective Ceiling (CLR). The Effective Ceiling (CLR) is normally approximately 0.8 times the weapon system's maximum ceiling.

There is one more complication involving AA values and this is to do with the Typical Target Dispersion (TDi) factor used in calculating weapon WCPCs. Aircraft targets in WWII generally appeared in two forms, which were high altitude targets or low-medium altitude targets. The two types of target demanded two main types of AA guns. These were generally light AA guns (usually 40mm calibre or less) and medium to heavy AA guns (usually 75mm calibre or above). [272] High altitude targets could only be

engaged by medium to heavy AA guns. Medium altitude targets were engaged by both types of AA guns. Low altitude targets were usually engaged by light AA guns, MGs and other small arms.

The problem is that the two aircraft target types have distinct dispersions. High altitude aircraft are much further away from the firer than low altitude aircraft, more commonly fly alone and will be further apart in formation. Aircraft attacking at low altitude are usually close to the firer and attack in concentrated groups, or waves, if possible. Aircraft attacking singly and at low level would draw all the flak in the area. Against even a moderate light flak concentration this would be suicidal and the plane probably wouldn't survive for very long.

To take account of varying aircraft Typical Target Dispersion (TDi) factors, AA guns with calibre 75mm and over have a TDi factor equal to 4,000 against aircraft. This value is used in recalculating the AA gun's WCPC value before using it to calculate Relative Anti-Aircraft Value (AA). Against ground targets these same guns still use a
TDi factor equal to 3,000. For AA guns with calibre 40mm and less, the TDi factor remains equal to 3000 for all aircraft and ground targets. Heavy Machine Guns (HMGs) called Anti-Aircraft Machine Guns (AAMGs) are treated as HMGs for all purposes, including calculating AA values. These weapons also retain their original TDi value equal to 2000 for all aircraft and ground targets.

We need to measure the relative anti-aircraft value of a weapon system or squad firing in a stationary mode against aircraft for a period of one hour. One hour is used as this is the time period specified in the WCPC Rate of fire (RF) factor. The Relative Anti-Aircraft Value (AA) is therefore purely an offensive value against aircraft, and we will only use offensive factors, and factors which are both offensive and defensive. We can also remove factors related to battlefield mobility or operational range.

For non-mobile weapon systems or squads , the Relative Anti-Aircraft Value (AA) is given by,

$$AA_{Non\ Mobile\ Wpn\ Sys\ or\ Squad} = Roundup\left(\left(\sqrt{\sum_{1}^{x} WCPC_{x\ AA\ Wpns} * TRF * FCE * CLR}\right)/5\right)$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all anti-aircraft capable weapons in the squad or weapon system crew (x = all AA capable weapons), or the WCPC of the primary weapon in an anti-aircraft weapon system (x =1 for AA guns).

CLR is the effective ceiling (in kms) of the most powerful AA weapon in the squad, crew, or the AA gun. The CLR is = 0.8 times the AA gun's maximum ceiling.

There are three provisos in using the above equation which are as follows.

- AA guns with calibre 75mm and over have a TDi factor equal to 4000 when calculating the WCPC value.
- For non-AA weapon systems, the squad or weapon system crew must have at least 1 LMG, 5 rifles or 5 SMGs to have an AA Factor greater than zero.
- The Multi Barrelled Effect (MBE) rules do not apply to WCPC values used for calculating AA values for multi barrel AA guns.

***

Note, if a weapon system crew have more than 40 rifles or SMGs then they will likely have sufficient firepower to generate a Relative Anti-Aircraft Value (AA) equal to 2. If a weapon system crew have more than 160 rifles or SMGs then they will likely have sufficient firepower to generate a Relative Anti-Aircraft Value (AA) equal to 3. The antiaircraft values for very large artillery pieces are generated through the large numbers of armed personnel servicing these weapons when they are deployed. [273]

The reader should also note that this use of secondary small arms is also used in calculating Relative Anti-Armour Values (AT) where there is no primary AT weapon in the weapon system being considered. However in this case the accumulation of many small arms with the weapon system's crew does not increase the AT value (unlike the AA value above). This is due to the way armour works: namely that if the AFV's armour is simply

too strong then increasing the amount of small arms fire will still have almost no effect. With aircraft there is little or no armour, so the amount of small arms fire will have a direct effect on the amount of damage sustained.

***

For MFMs the Relative Anti-Aircraft Value (AA) is given by,

$$AA_{MFM} = Roundup\left(\left(\sqrt{\sum_{1}^{x} WCPC_{MFM} * RFE * FCE * ASE * CLR}\right)/5\right)$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all anti-aircraft capable LMGs and larger weapons on the Mobile Fighting Machine (MFM) (x = all AA capable weapons >=LMGs). Note, in this case the weapon WCPCs are simply added together and not added using any Multi Barrel Effect (MBE) rules. Thus for multiple barrel AA guns firing at aircraft the MBE effect does not apply. Also note, MGs mounted in the front superstructure and turret mantlet on tanks are not considered anti-aircraft capable.

CLR is the Effective Ceiling (in kms) of the most powerful AA weapon on the MFM. The CLR = 0.8 times the AA weapon's maximum ceiling.

There is one proviso in using the above equation which is,

- Vehicles with no anti-aircraft capable LMG or larger gun can include crew-manned small arms, but they must have a crew with at least 5 rifles or 5 SMGs to have an AA value greater than zero.

***

b. Relative Anti-Aircraft Value (AA) for Aircraft

As one would expect, calculating the AA value for aircraft is quite different to that for land based weapon systems. The Relative Anti-Aircraft Value (AA) for aircraft is a measure of the aircraft's ability to engage offensively and defensively in air to air combat.

As we have seen above, the AA values for ground based weapons primarily involve firepower, range (ceiling) and fire control. The AA value for aircraft also uses these factors, but in addition must include factors for the overall flight capabilities of the aircraft. The flight capabilities should include the overall flight envelope of the aircraft which includes manoeuvrability, speed, rate of climb and rate of dive, as well as the aircraft's radius of operations. All these factors have a strong influence on any aircraft's ability to attack in air to air combat, and with the exception of radius of operations, a strong influence on any aircraft's ability to defend in air to air combat.

We need to measure the relative anti-aircraft value of an aircraft moving and fighting against enemy aircraft for a period of one hour. One hour is used as this is the time period specified in the WCPC Rate of fire (RF) factor. In calculating the aircraft's firepower we only include weapons which are capable of AA fire, which is usually only aircraft mounted weapons. [274] In calculating the WCPC values for aircraft mounted weapons we included factors for weapon range and fire control accuracy (the RN (range), A and AE factors). In addition the MOF, RA and SpMvr factors include all the relevant parameters to measure the aircraft's overall flight envelope.

The Relative Anti-Aircraft Value (AA) is an offensive value against aircraft, so we would normally only use offensive factors, and factors which are both offensive and defensive. However in this case we are also including the SpMvr as an offensive and defensive factor. [275]

For aircraft the Relative Anti-Aircraft Value (AA) is given by,

$$AA_{Aircraft} = Roundup\left(\sum_{1}^{MBE} WCPC_{AA\,Wpns} * MOF * RA * \left(SpMvr\ /\ 5\right) * CL\right) / 5$$

where the (capital sigma) WCPC summation is the sum of WCPCs for all anti-aircraft capable MGs and larger weapons on the aircraft, added up using modified Multi Barrel Effect (MBE) rules.

There are two provisos in using the above equation which are as follows.

- For aircraft <u>not</u> classified as fighters, night-fighters or fighter-bombers, <u>the RA value is fixed at 1.5</u>. This is because the Radius of Action (RA) was very important in increasing the offensive air to air capability of fighters attempting to find and intercept enemy aircraft. For other aircraft types the RA factor increased their overall attack capability against ground targets, but did not give the aircraft much increased air to air capability when under air attack.
- Fighter-bombers should have their Relative Anti-Aircraft Value (AA) (and Relative Overall Defence Factor (DEF), refer above) <u>reduced by approximately 1 when executing ground attack sorties with bombs and/or rockets</u>. This is due to the loss of manoeuvrability, speed and range when carrying heavy ordnance. Obviously jettisoning the bombs removes the problem, but this results in a failed primary mission and the equations assume aircraft execute their primary mission.

***

6) Relative Fortification Destruction Effect (FDE)

We now come to a parameter quite often underestimated in many military simulations and war games. This parameter is however the main reason for the existence of several types of ordnance. The FDE value is a measure of the weapon system's or squad's ability to destroy fortified and entrenched positions. 'Fortified' in this discussion primarily comprises bunkers, pillboxes, forts, trenches and dugouts. To a lesser extent it also includes most types of improved defensive positions such as barbed wire fences, tank traps, tank ditches, and other infantry and tank obstacles. It does not include minefields.

There are some similarities between the way armour and fortified positions work. They both possess a 'defensive shell' which usually needs to be penetrated to effect destruction. For fortified positions this defensive shell usually consists of reinforced concrete, earth works, bricks, wood, sandbags or similar materials. A tank may take any number of small anti-

tank hits and remain unaffected, or it may sustain a single large anti-tank round which penetrates the armour and destroys everyone and everything within. In the fortified position's case, a large number of small shells may have little or no effect on a bunker or pillbox; whereas a single large shell could penetrate the 'defensive shell' of the position and destroy it completely.

There are also some key differences between armour and fortified positions as well. Firstly, AFVs can be destroyed by relatively small amounts of high explosive once penetrated. Fortified positions are much larger and more dispersed, so they require large amounts of high explosive to ensure destruction. Secondly, due to the softer and lower strength materials used in fortified positions (they are not usually made of steel), large amounts of high explosive inflict relatively more damage than on armour, without actually penetrating the position.

On balance, the most important factors in determining the FDE for a weapon system are the mass of the projectile impacting the position (along with the proportionate HE content) and the accuracy of delivery. Note, the FDE factor is not equivalent to the Number of Potential Targets per Strike (PTS) factor used in calculating WCPC values. The latter is concerned with the 'destructive area' of the weapon system against unfortified and dispersed soft targets. As such it has no penetration parameters included.

For all land based weapon systems or squads , the Relative Fortification Destruction Effect (FDE) value is given by,

$$FDE_{Land\ \ Based\ \ Wpn\ \ Sys\ \ or\ \ Squad} = Roundup\ \left(\sqrt{P\ Mass} * A * 10\right)$$

where: *PMass* is the mass (in kgs) of the largest explosive charge that can be assembled and delivered using normally available equipment within a squad [276] , <u>or</u> the projectile mass of the standard high explosive round from the primary weapon in the land based weapon system.

A is the Accuracy (A) factor used in calculating the WCPC for the squad or weapon system being considered. For squads the A value is that used for grenades.

There are five provisos in using the above equation which are as follows.

- Squads, vehicles and weapon-system crews with no LMG or larger gun, must have at least 5 rifles or 5 SMGs to have a FDE factor greater than zero.
- Squads must have more than 10 stick hand grenades to have a FDE value greater than 1.
- Flamethrowers are assumed to have RF and PTS factors equivalent to an average 200mm howitzer. Therefore their FDE factor is calculated assuming a 'projectile mass' equivalent to a 200mm howitzer (approximately 112kg).
- Combat pionier squads were usually equipped with a variety of mines and special assault charges. These result in an average WCPC increase of approximately 40% over equivalent rifle squads. In addition the FDE is calculated based on the mass of mines or assault charges these units normally used to destroy strongpoints. [277] Note these units also have considerably lower Tactical Responsiveness Factors (TRF) and Concealment and Protection Factors (CPF), because they were lugging around this heavier equipment.
- If squads are close assaulting a fortified position (refer Relative Assault Attack and Defence Strengths (AAS and ADS) below), their FDE factor is multiplied by 4. This takes into account the increased accuracy of infantry delivered explosive charges at virtually point blank range.

***

Without the FDE factor, one would be hard pressed to justify the existence of some weapon systems. This is particularly the case for super heavy corps artillery, whose purpose was essentially to take the destructive effects of a large plunging shell to the extreme. The smallest super heavy corps artillery projectile was usually over 100kg. These weapon systems were usually broken down into multiple loads for transport and took a long time to deploy; sometimes days for the heaviest pieces. They also had a

very low rate of fire, were very expensive and required relatively large logistical support infrastructures. Their Relative Overall Attack Factor (ATT) and Relative Anti-Personnel Value (APer) are often surprisingly low for such large weapons, which is mostly due to their very low rates of fire. Nevertheless when Super Heavy Corps Artillery was used correctly, most often in static warfare or against strong fortifications during the initial stages of a battle, these ‘big smashers’ of the army could destroy the heaviest fortifications and rapidly reduce problematic urban terrain to rubble. This is evidenced by the very large FDE values for some of these weapon systems.

***

For aircraft , the Relative Fortification Destruction Effect (FDE) value is given by,

$$FDE_{Aircraft} = Roundup\left(\sqrt{P\,Mass} * A * AE * 10\right)$$

where: *PMass* is the projectile mass (in kgs) of the standard high explosive round from the largest aircraft mounted weapon, <u>or</u> the mass of the largest air launched weapon on the aircraft (bomb or rocket).

A is the Accuracy (A) factor and AE is the Aircraft Mounted Weapon Effect (AE) value used in calculating the WCPC for the aircraft mounted weapon, or aircraft launched weapon, on the aircraft being considered.

There is one proviso in using the above equation which is,

- Aircraft which are not carrying any air launched weapons (i.e. bombs or rockets), must have at least one 12mm MGs or a larger weapon, in order to have a FDE value greater than zero.

***

For land based weapon systems the A factor is not as critical as it is for aircraft weapons when determining FDE values. This is because fortified positions don’t move and once the position and range of the fortified

position were established, even relatively inaccurate land based weapon systems were able to consistently hit the target. For aircraft, however, this was not the case during WWII. Even with the target position well established and even visible, aircraft often had problems hitting the target with any consistency. In addition their ability to repeatedly hit any target was strongly influenced by flak, weather, navigation and enemy aircraft. [278]

Aircraft capable of more accurate weapon delivery and able to carry a heavy bomb had significantly higher FDE values. The best example of this is the somewhat maligned Ju-87, which we are repeatedly reminded was vulnerable to enemy fighters. However, the Ju-87 was designed specifically for one purpose, and that was to deliver 500kg bombs onto a target as accurately as possible. In the event, the Ju 87 remained the most accurate dive-bomber of WWII and was unsurpassed in WWII for its ability to provide true 'ground support' or 'close air support' (CAS) for attacking infantry and armoured units. [279] Consequently the FDE value for this aircraft is higher than any other generally available type in WWII, and comparable to super heavy corps artillery. This explains why the Ju-87 was used successfully as 'flying artillery'; able to reduce strongpoints relatively quickly and without the potential battle loosing delays due to the laborious process of deploying very heavy artillery.

***

7) Relative Armour Defence Strength (ARM)

The ARM value of a weapon system is a measure of the protection afforded to it by armour and only applies to land based Mobile Fighting Machines (MFMs). The ARM value includes effective armour protection changes due to the vehicle's size and shape. This includes sloping armour, open top structures and shot traps. Any armour on non-mobile weapon systems (such as gun shields) is incorporated in the relevant Concealment and Protection Factor (CPF). Any armour on aircraft is included in the aircraft's Durability Factor (DUR).

MFMs with armour are commonly known as Armoured Fighting Vehicles (AFVs). In order to qualify as an AFV, the MFM must have an

ARM value of 1 or more. This is important because it determines whether the vehicle is classified as a 'hard' or 'soft target'. Hard targets are attacked with the Relative Anti-Armour (AT) value while soft targets are attacked with the Relative Anti-Personnel (APer) value. [280]

The combat model for these two types of attack and defence are normally completely different. In the AT vs. armour model there is usually a square relationship between the AT/ARM ratio and the probability of a 'kill' resulting from penetration. This often takes a form similar to the following equation.

$$Kill\ probability = Const * \left(AT / ARM\right)^2$$

This means the chance of a kill decreases rapidly with a decreasing AT/ARM ratio. This simulates the fact that a multitude of weak AT hits on strong armour will still only have a low probability of inflicting fatal damage. The result is that AFVs are much less susceptible to cumulative mass fire from relatively weak AT weapons, and is the reason why the arms race between AT and ARM values during WWII was so critical. Note, the Constant in the above equation is for example only, and is usually a function of a multitude of other variables such as terrain, weather, deployment, etc.

In the APer vs. soft target model there is no such square relationship between APer value and the probability of a 'kill' resulting from a hit, unless there are additional circumstances. These additional circumstances may include fortified defensive positions, in which case an equation similar to the AT vs. armour model may be used. More often, however, the level of fortification enhances the defence to a lesser degree than a square relationship because fortifications are more susceptible to mass fire.

Fortunately in calculating ARM, we have already done all the necessary work when calculating the MFM's Overall Combat Power Coefficient (OCPC). Relative Armour Defence Strength (ARM) is an essentially defensive parameter and hence only the relevant defensive factors from the OCPC calculation are used.

For land based motorised Mobile Fighting Machines (MFMs), the ARM value is given by,

$$ARM_{MFM} = PR * SSF * OTF / 20$$

Where PR, SSF and OTF are the Protection Factor (PR), Shape and Size Factor (SSF) and Open Top Factor (OTF) used in calculating the land based MFM's Overall Combat Power Coefficient (OCPC).

***

8) Relative Assault Defence Strength (ADS) and Relative Assault Attack Strength (AAS)

When combat occurs at almost point blank range, the condition is sometimes referred to as 'close combat' or more accurately 'close assault'. The most likely unit type to deliberately engage in a close assault is an infantry type squad (combat pionier squads are included here as a type of infantry squad). In more sophisticated military simulations one value is used to represent a weapon system's or squad's ability to defend against such an attack, and this is termed the Relative Assault Defence Strength (ADS). Similarly the ability to launch a close assault, or counter-attack against a close assault, is termed the Relative Assault Attack Strength (ASS).

The ADS and ASS values are only applicable to land based weapon systems and squads.

In determining the ADS and AAS for any weapon system or squad, the same factors come into play as those used in calculating the OCPC values, along with the resultant Relative Overall Attack Factor (ATT) and Relative Overall Defence Factor (DEF). The difference is that the importance of certain factors changes during close assault conditions, so the weighting of these factors in the calculation of ATT and DEF also change.

Examples of <u>increases</u> in factor weighting in close assault conditions include:

- Large increases in weighting for the Concealment and Protection Factor (CPF) and the Defensive Dispersion Factor (DDF) in infantry type squads.
- A large increase in WCPC values for explosive weapons in infantry squads due to the reduction in range (to virtually point blank range). Under normal combat conditions the Range (RN) and Accuracy (A) factors, used in calculating the WCPC for these weapons, severely limits their effectiveness. However under close assault conditions these limitations are largely removed.
- Increases in weighting for the Target observation and Indicator Devices (TID) sub-factor in MFMs. When considering the Fire Control Effect (FCE) factor in MFMs, the TID sub-factor is normally given only a 10% weighting under normal combat conditions. As the TID factor considers the number, quality and design of observation devices available to the vehicle's crew, the TID factor assumes much more importance in a close assault situation where any vehicle 'blind spots' are much more likely to prove fatal.

Examples of decreases in factor weighting in close assault conditions include:

- A very large reduction in the weighting of Relative Armour Defence Strength (ARM) on AFVs. This is probably the most striking example of a reduction in factor weighting due to close assault conditions. The thickness of armour in a tank under close assault is much less important than the ability of the crew to see the enemy (efficient observation devices), and have efficient fire control and crew function to bring as many weapons to bear as quickly as possible. If enemy infantry can get close to or onto a tank, they have a good chance of killing it. Even the heaviest tank can be disabled by a Molotov cocktail in the engine grills. The tank will almost certainly be killed outright by a *Tellermine* under a turret overhang, or attachment of a magnetic AT grenade (a *Heft Hohladung granate*). In these cases even thick armour is of little value. [281]

- The large decrease in WCPC values for artillery weapons due to the reduction in combat ranges (to virtually point blank). Under normal combat conditions the Range factor (RN) used in calculating the WCPC for these weapons has a huge influence on their effectiveness. However under close assault conditions the artillery's range advantages are removed.

After experimentation, and varying the weighting of the various factors that go into the ATT and DEF calculations above, it was found that the following equations best represent the weapon system's or squad's ATT and DEF values under close assault conditions, i.e. their ADS and AAS values.

***

a. Relative Assault Defence Strength (ADS)

For non-mobile weapon systems the Relative Assault Defence Strength (ADS) is given by,

$$ADS_{Non\ Mobile\ Wpn\ Sys} = Roundup\ \left(DEF_{Non\ Mobile\ Wpn\ Sys}\right)$$

where $DEF_{Non\ Mobile\ Wpn\ Sys}$ is the Relative Overall Defence Factor (DEF) for the non-mobile weapon system.

There are several things of note in this equation. Firstly, the Defensive Dispersion Factor (DDF) is 1 for all these weapons, which means they cannot use dispersion as a defensive measure. Secondly, armoured shields on AT guns and some artillery, which may benefit these weapons in close assault conditions, are already considered in calculating DEF and so are included in the ADS factor. Thirdly, the usual proviso that at least 5 rifles or 5 SMGs must be present to have a value greater than zero, <u>does not apply</u> in this case because the ADS factor is purely defensive and we have already established the DEF factor can never be less than 1.

For non-mobile weapon systems the defensive parameters were not significantly reduced during close assault. These weapons were already soft targets which were vulnerable to a whole range of enemy fire and received

almost no protection from armour. In these cases the weapon system's crew, who were almost always armed, were available to defend their weapon with small arms, and some of the larger weapons had very large crews. In fact most artillery pieces were better off defending against attacking infantry under all conditions, than defending against attacking tanks, artillery or aircraft. Heavy infantry weapon crews, such as those manning anti-tank or infantry guns, were particularly liable to come under close assault. These units often had LMGs in their organisation to defend against infantry assaults, and the crews themselves were armed and trained to respond to such assaults.

***

For infantry squads the Relative Assault Defence Strength (ADS) is given by,

$$ADS_{Squads} = Roundup\left(DEF_{Squads} * 2\right)$$

where DEF_{Squads} is the Relative Overall Defence Factor (DEF) for the infantry squad. Note, the Defensive Dispersion Factor (DDF) factor is greater than 1 for all squad types, which means they can use increased dispersion as a defensive measure.

The only unit type which had significantly increased defensive parameters in close assault conditions were infantry type squads. The main reasons for this are the Concealment and Protection Factor (CPF) and the Defensive Dispersion Factor (DDF) in infantry squads. Under close assault conditions the CPF factor is enhanced because infantry being close assaulted is most able to take advantage of terrain and cover at very close ranges. The DDF factor is a measure of the ability to disperse to avoid enemy fire, and infantry squads are the only unit with DDF factors greater than 1. Therefore they are the only unit type that can disperse over a given area. In close assault conditions this means the squad can be defensively dispersed over the whole area being close assaulted. Because the range is almost zero, this dispersion effectively means the defence is simultaneously coming from several directions.

***

For MFMs the Relative Assault Defence Strength (ADS) is given by,

$$ADS_{MFM} = Roundup\left(\left(DEF_{MFM} \,/\, ARM_{MFM} \right) * 2 \right)$$

Where DEF_{MFM} is the Relative Overall Defence Factor (DEF) and ARM is the Relative Armour Defence Strength (ARM), for the MFM.

There is one proviso in using the above equation which is as follows.

- If the ARM value for the MFM is less than 0.2, the ADS value is then equal to the DEF value. In this case the MFM is considered to get almost no protection from armour and it's treated the same as a non-mobile weapon system.

As discussed above, in close assault conditions some weapon system's defensive parameters are significantly reduced. This was particularly true for WWII AFVs which relied on armour for most of their protection. Most AFVs had limited vision devices and blind spots which enabled close assaulting infantry to approach the vehicle and use explosive charges, grenades, hollow charge weapons, mines, Molotov cocktails and flamethrowers to exploit any weaknesses in the armour protection. In addition the power of many infantry close assault weapons, particularly in the second half of WWII, meant that infantry could deal with the heaviest armour. [282] The equation above eliminates armour as the main source of defensive strength on AFVs. Thus the ADS value for AFVs is effectively its defensive strength due to the many more important factors which enable the AFV to survive a close assault.

An interesting result of this analysis is that certain types of MFM turn out to be more difficult to close assault than their overall combat power would suggest. These vehicles include Armoured Personnel Carriers (APCs), certain well designed armoured cars and lightly armoured self-propelled AA guns. For example, armoured self-propelled AA guns often have sufficient armour to partially protect them from small arms fire, do not have vision restrictions as their crews have all round open vision, possess a

weapon which is lethal to infantry at very short and long range, and have the fire control systems to rapidly acquire and hit any target. Consequently these vehicles were generally more difficult and dangerous for infantry to close assault than even heavy tanks.

***

b. Relative Assault Attack Strength (AAS)

For calculating Relative Assault Attack Strength (AAS) all weapon systems and squads are divided into three categories. These are:

1. **Direct fire weapons** , which includes separate light infantry weapons, heavy infantry weapons (including mortars, infantry guns and AT guns), AA guns and MFMs.[283]
2. **Indirect fire weapons,** which includes all types of artillery and rocket artillery.
3. **Infantry squads** .

***

For direct fire weapons , except flamethrowers, the Relative Assault Attack Strength (AAS) is given by,

$$AAS_{Direct\ \ Fire\ Wpns} = Roundup\ \left(ATT_{Direct\ \ Fire\ Wpns}\ /\ 2\right)$$

where $ATT_{Direct\ Fire\ Wpns}$ is the Relative Overall Attack Factor (ATT) for the direct fire weapon system.

For flamethrowers and flamethrowers on AFVs, the Relative Assault Attack Strength (AAS) is given by,

$$AAS_{Flamethrow\ \ er} = Roundup\ \left(ATT_{Direct\ \ Fire\ Wpns}\ *\ 2\right)$$

***

For indirect fire weapons the Relative Assault Attack Strength (AAS) is given by,

$$AAS_{Indirect\ \ Fire\ Wpns} = Roundup\ \left(ATT_{Indirect\ \ Fire\ Wpns} / 4\right)$$

where $ATT_{Indirect\ Fire\ Wpns}$ is the Relative Overall Attack Factor (ATT) for the indirect fire weapon system.

***

For infantry squads the Relative Assault Attack Strength (AAS) is given by,

$$AAS_{Squads} = Roundup\ \left(ATT_{Squads} * 2\right)$$

where ATT_{Squad} is the Relative Overall Attack Factor (ATT) for the infantry squad.

There is one proviso applicable to all three ASS equations above, which is as follows.

- A weapon system crew, squad or MFM, with no LMG or larger gun, must have at least 5 rifles or 5 SMGs to have an AAS factor greater than zero. A flamethrower is considered a ‘larger gun’ for this purpose.

***

The only unit type which has significantly increased offensive parameters in close assault conditions are infantry type squads, which is why these units are likely to attack using close assault. There are several reasons for this.

Firstly, the range is reduced to the point where infantry squads can utilise the full range of explosives and other devices available to them, while at longer ranges they are limited to small arms fire which is ineffective against armour and fortified positions (in WWII this generally also included AT rifles).

Secondly, infantry can turn their Defensive Dispersion Factor (DDF) into an offensive parameter. The DDF factor is a measure of the ability to disperse to avoid enemy fire and infantry squads are the only unit with DDF factors greater than 1 (they are the only unit type that can disperse over a given area). In close assault conditions this means the squad can be dispersed in attack <u>and</u> because the range is almost zero this dispersion effectively means the attack is simultaneously coming from several directions.

Thirdly, a close assaulting infantry squad is most able to take advantage of terrain and cover at very close ranges while attacking. Hence infantry will always be more inclined to close assault in dense urban, forest or jungle type terrain.

One of the most famous examples of the results that can be achieved using infantry close assault tactics, is the German *Sturmbatallions* developed in late WWI. These Battalions were probably the first time a modern army developed infantry tactics specifically around the concept of close assault. When used with infiltration tactics, combined arms tactics and with specialised assault equipment, the *Sturmbatallions* demonstrated how effective close infantry assaults can be. They were the predecessors to the combat pionier and combat engineer units of WWII.

From the discussions above it becomes obvious that the best defence against infantry close assault is friendly infantry. Any military commander that allows his artillery and AFVs to be close assaulted without friendly infantry support is either incompetent or desperate, and is probably already losing the battle. Any military simulation combat model must simulate the ability of friendly infantry to provide protection for heavy weapons and vehicles against enemy close assaulting infantry. Thus if a tank is in dense urban terrain with infantry support and is close assaulted by enemy infantry, then the combat model must simulate the overall ADS value as being closer to that of the defending infantry than that of the tank.

***

9) Relative Overall Mobility (MOB)

The mobility and manoeuvrability of a weapons system or squad at the tactical and operational level is termed the Relative Overall Mobility (MOB). In calculating some of the specific combat attributes above, the factors for mobility of the weapons system or squad were removed. However mobility is critical to overall combat power and the Relative Overall Mobility (MOB) is included in the OCPC calculation, as well as the overall ATT and DEF combat attributes.

In discussing the mobility of a weapon system we need to distinguish between tactical and operational level mobility. In this work, the tactical level is defined as the level involving manoeuvre units of platoon size or smaller or gun batteries or smaller. [284] The operational level is defined as the level involving manoeuvre units of company size to army group level (Axis and Allied) and fronts (Soviet). [285]

At the tactical level, mobility refers to the ability of a weapon system or squad to move around the immediate battlefield. For land based units this includes the ability to overcome obstacles and negotiate cross country terrain, as well as the top speed over different surfaces. In the OCPC methodology, land based tactical mobility is incorporated in the Battlefield Mobility Factor (MOF) and the Half-Track Wheeled Effect (WHT) factor.

For aircraft, mobility at the tactical level focuses mainly on the flight envelope of the aircraft. In the OCPC methodology, aircraft tactical mobility is incorporated in the Battlefield Mobility Factor (MOF), Maximum speed and Manoeuvrability Factor (SpMvr) and the Ceiling Effect Factor (CL).

As the size of the battlefield and time considerations increase, military commanders have to start thinking about the logistics of supply and maintenance. These considerations are more operational in nature, but they still have a huge impact on tactical level decision making. For example, the operational range of an aircraft largely determines where its base airfield can be located, which is essentially an operational level decision. But the airfield's location has a direct impact on the maximum time the aircraft is able engage in combat, which is a tactical level consideration for the aircrew and mission planners on every sortie. For tanks it's a similar story.

This type of tactical and operational overlap often leads to different definitions of what is tactical or operational. The best compromise is to call this level tactical-operational.

The most significant tactical-operational mobility factor for all weapons systems is the operational range or radius of action. In the OCPC methodology, land based tactical-operational mobility is incorporated in the Range of Action (RA) factor, and for aircraft it is incorporated in the Radius of Action (RA) factor.

***

For MFMs the Relative Overall Mobility (MOB) value is given by,

$$MOB_{MFM} = Roundup\left(MOF * WHT * RA * 10\right)$$

MOB_{MFM} considers mobility at the tactical and tactical-operational level.

Note, in the OCPC methodology, horse teams, cars, trucks, tractors, motorcycles, armoured trains, and semi or fully tracked prime movers, are considered to be MFMs (albeit with very little armament and protection). Their mobility, and the mobility of weapon systems and squads they may be transporting, is thus treated in the same way as any other ‘fighting vehicle’ (with attention to the various equations’ provisos).

***

For aircraft the Relative Overall Mobility (MOB) value is given by,

$$MOB_{Aircraft} = Roundup\left(MOF * \sqrt{SpMvr} * CL * RA * 10\right)$$

$MOB_{Aircraft}$ considers mobility at the tactical and tactical-operational level.

***

For non-mobile weapon systems and squads , one might consider the MOB value to be zero. However ‘non-mobile’ in this context means either stationary (emplaced), or not having a motor or other power source, such as a steam engine or horses, integral to the weapon system. Note, these systems may still be moved but this requires additional transport which is not integral to the weapon system (e.g. a horse team with artillery hitch and limber, or an artillery tractor). Obviously squads can march on foot and many of the lighter weapon systems can be manually pulled or manhandled to varying degrees.

For infantry squads the Relative Overall Mobility (MOB) value is a judgemental factor determined from the amount of heavy equipment the squad has to carry, and the presence of any integral (to the squad) man-powered transport such as bicycles. This is based on a MOB value equal to 3 for a lightly equipped rifle squad walking cross-country on flat mixed terrain and in good weather.

For non-mobile weapon systems the Relative Overall Mobility (MOB) value is also somewhat judgemental. The approximate MOB value for these weapons is given by,

$$MOB_{Non\ Mobile\ Wpn\ Sys} = \left(\left(\left(1/\sqrt{Weight\ \ in\ action}\right)*10\right)+0.1_{Lg\ Wheels}+0.1_{Pneumatic\ Tyres}+0.2_{Design}\right)$$

where weight in action is the unlimbered weight of the weapon system ready for action (in kgs), 0.1 is added for large wheels and/or pneumatic tyres, and 0.2 is added for mobility enhancing design features.

There are three provisos in using the above equation which are as follows.

- The weight in action must be less than 1500kg, otherwise is equal to zero.
- The weapon system must have permanently attached wheels ready for movement or be light enough to be carried by one man.
- The $MOB_{Non\ MobileWpn\ Sys}$ cannot exceed the value of 3, i.e. that of walking pace if the weapon is carried.

***

Some weapons systems have a reasonable weight in action (e.g. 100-120mm heavy mortars at around 500kg), but have no permanent wheels and/or have to be dismantled for transport. These weapon systems were simply not designed for manhandling and the components are usually too heavy to be manually carried. These weapon systems have a MOB value of zero.

An example of the application of the equation above is the 3.7cm *Panzer Abwehr Kanone* (PAK) 36 anti-tank gun. It had a weight in action of 432 kg, large wheels, pneumatic tyres and a lightweight efficient split trail carriage. This made the PAK 36 highly manoeuvrable for an AT gun, able to be moved quickly by four men. Its MOB value, without any form of transport and relying only on the gun's crew, is therefore 0.88.

Those weapon systems with a MOB value of zero require some form of horse or motorised transport to move, or are considered static emplacements.

***

10) Supply Demand Factor (SDF)

The SDF factor is a measure of the minimum amount of supply and support needed by a weapon system or squad to remain operational during combat operations. 'Support' includes a component for maintenance, repair and possible recovery of the weapon system, as well as simple supply. The very high combat power of certain weapon systems comes at a high price in supply and support infrastructure needed to support them.

The SDF factor is a critical component for measuring a force's relative Supply Distribution Efficiency (SDE), detailed in Part I 8. [286] The impact of the SDF factor and SDE efficiency on combat and mobile operations is often underestimated (or even ignored) in many tactical-operational level simulations. This usually leads to unrealistic results and ignores fundamental strengths or weaknesses of certain armies during specific WWII campaigns.

The Supply Demand Factor (SDF) for individual weapon system or squad types is expressed in units equivalent to 100kg per day or 0.1 metric tons per day. This is also a useful way for the reader to 'visualise' the typical amount of supply and support needed by an individual weapon system or squad to remain fully operational during intense combat operations. In the calculations of individual SDF values it is assumed that,

- The main weapons (or weapon) involved are in action for approximately 1 hour in every 24.
- Motorised weapon systems (e.g. AFVs) move around the battlefield for 12-14 hours in every 24.

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a. SDF Values for Land Based Weapon Systems and Squads

In this section we will include three areas of supply and support required for the land based weapon system or squad to achieve the Overall Combat Power Coefficients (OCPCs) detailed in this database methodology. These are ammunition, fuel and general support. Food and water consumption by the weapon system's crew or squad is not explicitly included in the SDF factor, but is included when calculating the overall force's Supply Distribution Efficiency (SDE). [287]

The relative Supply Demand Factor (SDF) is given by,

$$SDF_{Land\ Wpn\ Sys\ or\ Sqd} = \left(Ammo_{All\ \mathrm{Pr}imary\ Wpns} + Fuel\right) * Support$$

where: *Ammo* is the minimum ammunition required to maintain the Rate of Fire (RF) value used in calculating the weapon system's or squad's WCPC value.

Fuel is the minimum fuel Mobile Fighting Machines (MFMs) require to maintain the mobility used in calculating the MFM's Battlefield Mobility Factor (MOF) value.

Support is a fixed value representing the minimum maintenance, repair and possible recovery different weapon system types need to remain operational.

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$Ammo_{All\ Primary\ Weapons}$ in the SDF equation (above) is calculated using the following equation,

$$Ammo_{All\ Primary\ Weapons} = \sum_{x=1}^{x=n} \left(RF_x * P\,Mass_x * MBE_x / 100 \right)$$

Where: *n* is the number of weapons in the squad or MFM (x = n for all weapons), or the primary weapon in a non-mobile weapon system (n =1). For example, for tanks the primary weapon and all permanently mounted MGs are included, while for infantry squads all small arms and grenades are included. Small arms included for self-defence only, such as gun crew small arms or transport crew small arms, are not included. It is assumed the latter are rarely fired.

RF is the Rate of Fire (RF) value used in calculating the particular weapon's WCPC value.

P Mass is the typical projectile mass (in kg) of a single round from the particular weapon. Note, *P Mass* was also used in determining a weapon system's or squad's relative Fortification Destruction Effect (FDE) value. [288]

MBE is the Multi Barrel Effect (MBE) value used in calculating the particular weapon's WCPC value.

There are two provisos in using the above equation which are as follows:

- SMGs and pistols are divided by 200 and not 100. This takes into account the lower amount of time these weapons would be

continuously firing compared to LMGs, HMGs, and rifles.

- The P Mass value for rocket artillery is the mass of the rocket before launch. [289]

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Fuel in equation the SDF equation (above) is calculated using the following equation,

$$Fuel = Engine\ Power_{MFM} / 50$$

Where: $Engine\ Power_{MFM}$ is the engine power (measured in horse power) used in determining the Mobile Fighting Machine's (MFM's) Battlefield Mobility Factor (MOF) value. Note that non-mobile weapon systems and squads have a *Fuel* value of zero. However towed or carried weapon systems and squads use transport such as trucks or prime movers, and these have a separate SDF value which includes fuel consumption.

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Support in equation (1) is a fixed value depending on the type of weapon system being considered, as follows,

- 1 for light infantry weapons and light infantry weapon equipped squads.
- 1.05 for heavy infantry weapons, AT guns, AA guns, artillery and rocket artillery.
- 1.1 for all wheeled vehicles without tracks which are not artillery tractors or prime movers.
- 1.15 for halftracks, artillery tractors or other prime movers.
- 1.2 for fully tracked vehicles which are not artillery tractors or prime movers.

Support represents the relative maintenance, repair and possible recovery that different weapon system types need to remain operational. Obviously tanks and heavy towing vehicles require a large degree of support compared to other weapons.

Note, very heavy towed weapons such as super heavy artillery may ultimately utilise several *Support* values. For example, a heavy artillery piece might need to be split into two loads for transport, each requiring a dedicated prime mover. The total *Support* for this weapon to remain operational will therefore amount to 1.15+1.15+1.05 = 3.35.

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b. SDF Values for Aircraft

In general, SDF factors and the resultant Supply Distribution Efficiency (SDE) for combat aircraft are even more underestimated (in military simulations) than for land based forces. It is often assumed aircraft are always in supply, presumably because aircraft can somehow fly supplies in, or are based near stockpiled supplies.

In fact aircraft have a ferocious appetite for fuel, ammunition and spare parts. During WWII, bombs, rockets, bullets, cannon shells, fuel and spare parts usually arrive on the airfield in trucks, and very little was flown in. If the airfield is located forward with advancing spearheads or remote from a railhead, a considerable amount of overland transport is required, even if sufficient supplies are available. One only has to look at air operations in theatres such as the Pacific in WWII to realise that aircraft without adequate overland or ship borne supplies soon suffer dramatic operational readiness loss.

In addition aircraft are considerably more prone to readiness loss due to accidents, the weather and machine fragility. Even a minor technical fault can ground an aircraft, which is basically a useless scrap of metal until fixed. For these reasons aircraft ‘support’ values (used in the previous entry) would be higher than almost any other weapon system type, in the region of 1.3 to 1.4 for comparison purposes. The difficulty of keeping a large air fleet operational is one of the key features of an air force’s Relative

Overall Combat Proficiency (ROCP), easily as important as quality of pilot training. It explains why successful air forces in WWII (and even more so today) had such large support infrastructures. An air force's SDE is one of the key reasons why a small but highly operational force can often defeat, or hold its own, against a much larger number of enemy aircraft. Only those aircraft actually flying combat missions count!

For the purposes of Operation Barbarossa, and WWII and campaigns in general, the following aircraft SDF factors should be used in determining the effect of an air fleet's supply demand on the overall force's supply demand.

Aircraft SDF Factors	
Single Engine Fighters	10
Single Engine Fight/Bombers	12
Twin Engine Day Fighters	16
Twin Eng Night Fighters	16
Twin Engine Fight/Bombers	20
Single Engine Ground Attack	20
Dive Bombers	24
Twin Engine Bombers	30
Four Engine Bombers	40
Long Range Recon	25
SR Recon /Army Coop	10
SR Recon Biplane/Army Coop	5
Seaplanes	15
Transport Aircraft	15

The figures above take into account that ground attack and bomber type aircraft use considerably more ammunition and fuel compared to other types. In addition it is assumed that a significant proportion of airfields will be located in rear areas near railheads, port facilities or stockpiled supplies. Airfields in these positions obviously require much less transport support than those in forward areas near the front line.

Despite the large number of aircraft involved in Operation Barbarossa, the impact on overall force Supply Distribution Efficiency (SDE) turns out

to be relatively small for all combatants. This was due to the immense land forces involved on the East Front. [290] However it was still significant, and consequently the supply demand from combat aircraft are included in the various combatant's Fully Integrated Land and Air Resource Models (FILARMs).

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[261] Refer Part Volume V 3. 9) – 'Relative Overall Combat Proficiency (ROCP): the ROCP of Soviet and Axis Forces from 1941-1945 - Axis and Soviet Relative Overall Combat Proficiency (ROCP) in 1941 - Weapon Density (WD) Effects on the 1941 German-Soviet ROCP'.

[262] Mathematically the OCPC does change slightly if the offensive and defensive nature of the factors are reconsidered, and then moved from one side of the equation to the other. However this is then manipulation of the original equations which brings us back to the initial debate of what constitutes an offensive or defensive characteristic.

[263] This is approximately three kilometres for most land based weapons, before taking into account any limitations due to the weapon system, optical system and fire control system. This includes anti-aircraft (AA) guns firing at land targets.

Naval and coastal weapons, on ships or firing out to sea, would have much greater ranges, even in direct fire mode (it is assumed they would be firing at visible ships). If firing in a shore bombardment mode, these weapons would be classified as medium to heavy artillery, and hence their indirect fire ranges would be used. As the OCPC methodology is primarily focused on the lethality of weapons against land targets, it is the latter which we would use to calculate the WCPC of weapons on warships.

[264] The Soviet 120mm Mortar M1938 was considered to be, and used as, artillery by the Red Army. For this reason its R factor is calculated as for an indirect fire weapon.

[265] During WWII, the only medium-heavy AA gun used frequently for indirect fire was the German 88mm Flak18/36. As well as doubling as an AA gun and AT gun, it was sometimes used to fire HE shells and double as artillery.

[266] MFMs which are indirect fire self-propelled artillery weapons are treated as artillery.

[267] For calculating R, light infantry weapons includes AT Rifles.

[268] For calculating R, indirect fire self-propelled artillery is treated as artillery. However, direct fire self-propelled guns are treated as direct fire MFMs.

[269] Appendix A – 'Armour Penetration Figures: Historical Test Results vs. Calculated Values'.

[270] These parameters for penetration were chosen because this information is most readily available for many weapons in WWII. However, for late war German infantry squads in particular (and to a lesser extent Western Allied infantry squads) this is a major disadvantage because they were equipped with some very powerful but short range AT weapons. For squads a shorter range would

provide more realistic AT values. However it also has to be borne in main that it was the short range and relative inaccuracy of these weapons were their greatest tactical disadvantage.

[271] The same parameters lead to efficient FCE factors against land and air targets. With AA guns, the absolute FCE is usually higher than most other weapon system types. We are interested in the Relative Anti-Aircraft Value (AA), and the relative FCE increase is similar for all side's AA guns.

[272] The definition of heavy, medium and light AA guns varies with countries. For example, the Germans called 105mm, 88mm and 37mm caliber flak guns, heavy, medium and light flak guns, respectively. Other countries often refer to 37-40 mm AA guns as medium AA guns, and 20mm AA guns as light AA guns. The definition here is closer to the WWII pilot's description; who would normally describe 40mm or less caliber AA fire as light flak, or more probably "xxxxxx light flak!" .

[273] The ability of infantry and ground troops in general to bring down low level aircraft is often underestimated. For example, in 1941 and 1942 the Red Army was chronically short of light flak guns. During this period 30-40% of the German ground attack planes lost to ground fire, were brought down by Soviet troops opening up with everything they had including rifles and SMGs. In addition German squads were trained to use their MG 34s as AA weapons if the opportunity arose and they weren't concerned about ammunition usage.

[274] In WWII it was possible to use rockets against enemy aircraft. However ground attack rockets were unsuitable or not adapted for this role, and it was rare for ground attack aircraft to fire rockets in this manner. The only significant use of rockets in air to air combat in WWII was on Me-110s, Me-410s, Me-109s and Fw-190s attacking large US bomber formations over occupied Europe from 1944. These rockets were adapted from a 210mm rocket mortar, and launched from tubes beneath the fighter's wings. The rockets weighed 112kg, had a 36kg warhead, were set to explode at preset ranges of 550-1100 metres, and needed to explode within approximately 15m to inflict serious damage on a B17. If a direct hit was obtained, one rocket would normally bring down a B-17 or B-24. N. Franks, Aircraft versus Aircraft, Grub Street, London, 1998, p. 132.

[275] SpMvr is treated as a defensive factor in the OCPC calculation. Refer Volume I, Part II 2. 4) g. – 'Methodology for Calculating a Weapon System's or Database Unit's Overall Combat Power Coefficient (OCPC) - Calculating an Aircraft's Overall Combat Power Coefficient (OCPC) - Maximum speed and Manoeuvrability Factor (SpMvr)'.

[276] For example, a German infantry squad often used a *Steilhandgranate* 24 bundled together with up to 6 cylindrical grenade warheads called *Handgranate* 43s, to make a more powerful anti-tank or anti-strongpoint explosive charge. The weight of this ' *Geballte Ladung*' or 'forceful/big charge' was around 3.7kg.

[277] Some combat pionier or assault engineer squads were also equipped with flamethrowers. However these were normally integrated at a higher platoon level within a combat pionier or assault engineer company, so there was not normally one in each squad.

[278] The sometimes stunning inaccuracy of the various strategic bombing campaigns in WWII, is a stark and graphic testament to the inability of high and medium level bombers to hit even large targets in broad daylight.

[279] The only aircraft that came close was the outstanding, but tiny, Henschel Hs 123 dive bomber and close support aircraft, which was supposedly obsolete at the outbreak of WWII. Aircraft like the Hawker Hurricane II, Hawker Typhoon, Fw 190F and Ilyushin Il-2 were much better able to survive enemy fighters, but none of these aircraft were ever able to achieve anything like the bombing

accuracy of the Ju 87 (of for that matter the Douglas SBD Dauntless or the Curtiss SB2C Helldiver): they were always much more effective at fast moving and relatively inaccurate interdiction missions. These aircraft are also extremely overrated as tank-destroyers, also largely due to their inaccurate weapons delivery (during WWII, tank kill claims by all these aircraft types were almost never ratified by after action ground reports, but this is another story). The Ju 87 proved to be so accurate (especially in the hands of an expert), that individual bunkers, pillboxes, buildings and gun emplacements were often singled out for close attention. The CAS (close air support) of the Ju 87 proved to be so 'close' that is was not uncommon for infantry to enter the bombed location before the debris had even settled. There were very few aircraft in WWII which any infantryman would have trusted with this level of accuracy. The Ju 87 was a true forerunner of modern CAS aircraft equivalents such as the lethal Fairchild Republic A-10. Interestingly, today, the A-10 is also vulnerable to almost all types of enemy fighter aircraft, but no one seems to find this a problem!

[280] MFMs with armour less than 1 but greater than 0.2 still get the benefit of armour protection during a close assault; refer to the Relative Assault Defence Strength (ADS) section. This is because these vehicles have sufficient armour in the form of gun shields, etc, to reduce the effects of small arms fire but not AT gun fire.

[281] The *Heft Hohladung granate* 3kg, was a German cone shaped grenade attached by strong magnets. Its shaped charge (HEAT) warhead could penetrate over 140mm of armour, enabling it to easily kill any WWII tank.

[282] For example, the advent of the *Panzerfaust* and *Panzerschreck* range of weapons meant that from 1944 it was basically suicidal for Soviet or Western Allied tanks to attack German infantry in urban or close terrain, without friendly infantry support. This was true regardless of the armour thickness on the tank in question.

[283] Self-propelled MFMs which mount indirect fire artillery weapons are treated as artillery.

[284] Refer Volume I, Part I 1. 4) – 'Military Simulations, and the General Structure of the Integrated Land and Air Resource Model - Studying Military History Using Operational – Strategic Simulations – Tactical, Tactical-Operational, Operational and Strategic Military Simulations'. Note, the Tactical Level encompasses all aspects of tactical and tactical-operational simulations, with space scales up to 300metres per hex. All physical combat is at this level. The definition of tactical and operational level is a grey area and there is often considerable overlap of these concepts in most publications.

[285] Ibid. Note the Operational Level encompasses all aspects of operational war game simulations, and only operational aspects and activities of strategic war game simulations, with space scales from 500 metres per hex upwards.

[286] Refer Part I 8. – 'Military Simulations, and the General Structure of the Integrated Land and Air Resource Model - Supply Distribution Efficiency (SDE)'.

[287] Ibid. The SDE calculation detailed in Part I 8. uses a figure for the total personnel strength to include a component for food and water consumption in a force's overall supply demand.

[288] The only difference here is for squads. In determining a squad's FDE value, *P Mass* is the largest explosive charge that could be assembled and delivered using normally available equipment within the squad.

[289] A more accurate SDF value would be obtained by using the mass of the round before firing instead of the projectile mass. I.e. the supply infrastructure has to supply the projectile and charge so

the total weight supplied is heavier than the projectile mass only. However, this is the same for all sides so the relative effect cancels out when considering relative SDF values for projectile weapons. For rocket artillery, however, the majority of the mass is the rocket itself and the warhead is relatively small. Complete rockets need to be supplied during combat and are expended very rapidly, so rocket units have large SDF values. This is one of the main reasons why rocket artillery was often used for short periods during the initial stages of an offensive.

[290] The effect of the air-fleet's supply demand on the overall force's supply demand was much more significant in the Western Desert and various Pacific campaigns during WWII (for example). In these theatres of war, the air and naval-air forces represented a much larger proportion of the overall forces present.

4. Resource Database Comments and Conclusions

The above detailed methodology enables the calculation of overall combat power and specific combat attributes down to individual squad, vehicle and weapon level. Our objective here is to create the individual database resources for the integrated land and air models of the various belligerent's armed forces to follow in Volume II to Volume IV of this work (Operation Barbarossa: the Complete Organisational and Statistical Analysis, and Military Simulation).

Although the methodology contains a great deal of detail, the subject is necessarily complex, especially if historical accuracy and true combat power are to be represented. This is vital to any military simulation or war game attempting to replicate realism. The weapon systems and squads defined in the initial stages of any model are the basic building blocks and foundation of the simulation. If the Overall Combat Power Coefficient (OCPC) values and the resultant combat attributes for the weapons are inaccurate or simply wrong, then this inaccuracy or error becomes magnified later in the simulation and combat model. If the objective is realistic and historically accurate results, then the simulation is severely disadvantaged in the best case, or fatally flawed in the worst case. This will occur no matter how well designed or well thought out the individual combat model is.

Another important reason for calculating the combat power of weapon systems accurately is that these values are needed for a realistic analysis of relative combat proficiency. The entire methodology defined in this volume is <u>independent</u> of the training, leadership and culture of the army or air-force which has the weapon in its inventory. The calculated OCPC values and the resultant combat attributes are inherent in the design and quality of the weapon itself. Hence a side with more powerful and effective weapons will have a decided advantage in combat, even though it may be facing an opponent with superior training and leadership, i.e. a higher combat

proficiency. This effect is defined as the Weapon Effect (WE) on Relative Overall Combat Proficiency (ROCP), and is examined in detail in Volume V (of this work). However, if the OCPC calculations are inaccurate this also leads to inaccurate estimates of a side's combat proficiency, which in turn automatically leads to additional inaccuracies in the simulation and combat model.

In setting out the methodology above, great care has been taken to balance the relative OCPCs and combat attributes between the various weapon systems. Thus the value of any specific combat attribute for non-mobile weapon systems, squads, mobile fighting machines and aircraft are balanced correctly relative to each other. For example, the Relative Anti-Armour Value (AT) of a Junkers Ju 87B in 1941 is 5. The AT value for a T-34/76B (Model 1941) in 1941 is also 5. [291] It can therefore correctly be said that the T-34/76B had a similar overall anti-armour capability as the Ju 87B at this time.

The specific combat attributes detailed are by no means the only ones a war game or military simulation designer may need. The ones detailed here are however the most commonly used. Using the basic factors used in calculating a weapon system's or squad's OCPC values, it is possible to formulate equations for additional combat attributes. The important thing to remember is we are interested in relative combat attributes, with the stress on 'relative'. All weapon systems are created and work within a frame work of relative time and contemporary weapons of the period. It is therefore usually a mistake to compare weapons from WWII to modern day weapons without considering all modern day attributes and circumstances. Similarly, it is pointless analysing the combat power of a weapon system in isolation. This sounds obvious, but it continues to be a source of amazement how often a weapon system's performance is 'analysed' in isolation and not compared to identical analyses of contemporary systems. [292] It is only the relative analyses of weapons systems to each other (and preferably contemporary ones) that are meaningful and useful.

Finally, the methodology in this volume for calculating OCPCs is geared around weapon systems that existed from 1914-1945. The same basic methodology can be applied to modern day systems but several

essential factors need to be added to incorporate technological advances since that time. This enhanced or modernised OCPC methodology must at least include additional factors for the following:

- All types of guided weapons, including AT, AA and air to air missiles.
- Advanced communication and command and control systems.
- Computer based fire control systems.
- Night targeting and fighting capability.
- All weather targeting and fighting capability.
- The special capabilities of helicopters.
- The advanced materials used in modern day armour and other armour innovations such as reactive armour.
- The advanced design features and material used in modern anti-tank ammunition design.

These factors could be added to those detailed in the methodology, or used to replace factors with more updated ones. Perhaps in a future project on the possible NATO vs. Soviet conflict that might have occurred in Europe in the 1970s or 80s.

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[291] Refer to the German and Soviet FILARM models (Volumes IIA and IIIA, respectively) for details on these weapon systems's calculated AT values.

[292] E. g. W. Wilbeck, Sledgehammers-Strength and Flaws of Tiger Tank Battalions in WWII, The Aberjona Press, Bedford, Pennsylvania, 2004. This is a 262 page book on analysing the combat power of Tiger tanks. Despite its length, at no point is the kill ratio against tanks and artillery weapons achieved, the percentage operational over time, the percentage lost as tactical or operational losses, etc, compared to any other AFV or weapon system in WWII. I.e. there is no 'relativity' in the arguments presented because the Tiger's performance figures are presented in complete isolation. Hence, the conclusions drawn as a result of this analysis in 'isolation' are very different from those that are drawn when the Tiger's figures are compared to identical figures for any other AFV from WWII.

Appendix A

Armour Penetration Figures: Historical Test Results vs. Calculated Values

In Part II 3. 4) we used the ability of a weapon system or squad to penetrate homogeneous armour plate sloped at 30 degrees from vertical at 1000 metres range (using its most common AT round), as one of the factors for calculating a weapon system's or squad's Relative Anti-Armour (AT) value.

Unfortunately, using specific armour penetration figures to calculate AT values causes a 'can of worms' to be opened regarding the 'correct' or true value. There are two main sources of angst in this area. Firstly, there are variations between different historical sources regarding penetration figures achieved on test ranges, sometimes even for the same weapon and ammunition. Secondly, there are often significant discrepancies between recorded armour penetration figures and projected penetration values calculated using physics equations.

Upon examining historical records of test firing we find variations in supposedly comparable figures for several reasons. These include:

i. The test figures come from similar tests (i.e. similar ranges and angles), but at different times and in different countries. The test armour brittleness, hardness and quality vary between different tests and different countries, i.e. varying Poldi or Brinell hardness type figures.

ii. The definition of a 'penetration' various from country to country. For example, German figures tended to include the whole round penetrating, whereas British test figures allowed for partial penetration. If the AT round is an APHE round, then total penetration is more desirable. If the AT round is a solid AP round, then partial penetration is still very important. British penetration figures in

particular, need to be treated with caution because in some cases as little as 20% of the round penetrating the armour is classified as ‘armour perforation’. [293]

iii. Different propellant charges were sometimes used to determine penetration using the same projectile. This means ammunition varied even though it may have had the same designation.

iv. The use of face hardened armour is used in some tests but not others, which affects AP ammunition considerably more than APC or APCBC ammunition.

On balance and with hindsight, it is not realistic to expect different tests in time and place to be identical. However, with careful historical research it is possible to eliminate a large proportion of the sources of variation. These include ensuring ranges and angles are as identical as possible, ensuring the same ammunition type is used, and ensuring the definition of a penetration is reasonably consistent. The largest factor outside historical control appears to be the armour hardness and quality used in test firing. This seems to vary depending on when, where and what country produced it. Despite this, surprisingly consistent figures emerge regarding penetration figures for the majority of AT weapons used during WWII.

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The second school of thought is to replace the historical test figures with projected penetration values calculated using physics equations . [294] To examine this option let as take the two basic physics equations involved. These are:

$$Pen = kmv^2 / d^2$$

Where *Pen* is equal to the armour penetration (in mm) of vertical armour plate i.e. at zero degrees strike angle, k is the coefficient that varies with armour quality [295] , m is the projectile mass (in kg), v is the projectile strike velocity (in m/s), and d is the projectile diameter (in mm).

***

The variation in velocity of the projectile as a function of distance is given by,

$$v = v_0 e^{-\left(cd^2 x / m\right)}$$

Where v is the projectile velocity (in m/s), is the muzzle velocity (in m/s), e is the exponential constant, d is the projectile diameter (in mm), m is the projectile mass (in kg), x is the distance the projectile has covered (in metres), and c is a coefficient representing the aerodynamic resistance to the projectile. This equation assumes the projectile trajectory is horizontal. [296]

The idea behind these equations is to eliminate variations in variables used in test firing figures and obtain a truer comparison of AT capabilities between guns. Applying these equations to some of the most well-known tank and anti-tank guns used during WWII and comparing them to historical test firing figures, we get the results shown in table Pen. The historical test data used in this table utilises the most consistent information available from reputable sources. Care has been taken to ensure that consistent ranges and strike angles are used for all the weapon systems considered. In addition the test ammunition chosen is of similar type, i.e. the standard ballistic capped AP round wherever possible. For a few selected weapons different sources of test data are used, which serves as an example of variations in test data for supposedly identical weapons.

Generally speaking, table Pen shows rather inconclusive results, although there are arguably some patterns.

- In 20 out of 26 cases the theoretical result is greater than that achieved in tests. In other words the guns did not perform as well as they theoretically should, if the muzzle velocities were as stated, and the ammunition was reasonably well designed and constructed. Interestedly, all the Soviet, British and American examples are in this category, although most of them are not too far below the mark (i.e. a 1- 10% error). For those weapons with an 11% or greater error there is

obviously something fundamentally wrong. It is unlikely the Soviet or Allied test armour was of superior quality to that used by the Germans (which would help explain the results, if this occurred), and in any case some of the German case studies also fall into this category. In these cases the most likely (and reasonable) explanation is that the muzzle velocities were not as high as stated (see below), or/and the ammunition design, construction and material was of inferior quality.

- In only 5 out of 26 cases the theoretical result is less than that achieved in tests. These are all German case studies, although most are close to the mark and within a reasonable error range (5% or less). The two cases with large errors (21-27%) are both relatively low muzzle velocity weapons, i.e. the 7.5cm KwK 37 L/24 and 3.7cm Pak 36 L/45. Again, it is unlikely these particular weapons were tested using inferior quality armour, and the most likely explanation is that the muzzle velocities were actually higher than stated.

- In only 1 out of 26 cases was the theoretical result within 0.4% of that that achieved in tests. This was the 8.8cm Pak 43 L/71. In other words this famous gun was as lethal as stated, and capable of destroying any tank in the world out to at least 2000 metres.

After experimenting with these equations, it became apparent that the only significant variable that is eliminated (by adopting a theoretical approach to penetration values) is k, the coefficient that varies with armour quality. By maintaining a constant k (in the calculated values) of 0.182, we effectively eliminated the test firing discrepancies due to armour quality. On the whole, the different test firing sources maintain consistent values for m, d, and x between tests, provided care is taken with the test data.

However, attempting to use the equations to obtain the 'true' AT capabilities of guns causes a whole new range of problems to be introduced, which in turn produce a range of introduced errors. The most significant ones are in the areas of c (the coefficient representing the aerodynamic resistance to the projectile), (the muzzle *v*elocity), and specific ammunition design and quality. The following sections highlight why these areas introduce significant errors in to the theoretical calculation of armour penetration.

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Table Pen

Calculated Armour Penetration Values versus Historical Test Data

	Typical AFV or AT Gun	Percentage Error %	Historical Test Results 30 deg, mm	Calculated Penetration 30 deg, mm	Calculated Penetration 0 deg, mm	Strike Velocity V, m/s	Muzzle Velocity Vo, m/s	Air Resistance Coefficient c	Projectile Diameter d, mm	Distance Covered x, ms	Projectile Mass m, kg
90mm M3 L/51^^	M36, Pershing	**-24%**	102	128	152	780	853	0.00000013335	90	914.4	11.1
8.8cm Pak 43 L/71	Tiger II, Nashorn	**0%**	165	164	196	904	1000	0.00000013350	88	1000	10.2
8.8cm KwK 36 L/56*	Tiger I	**2%**	100	98	117	698	773	0.00000013350	88	1000	10.2
8.8cm KwK 36 L/56*	Tiger I	**-5%**	102	108	128	732	810	0.00000013350	88	1000	10.2
8.8cm FlaK 18 L/56*	AT Gun/Flak	**1%**	106	105	125	723	800	0.00000013350	88	1000	10.2
8.8cm FlaK 18/36 L/56*	AT Gun/Flak	**-1%**	110	111	132	741	820	0.00000013350	88	1000	10.2
85mm ZiS-S-53 (L/54.6)	T34/85	**-18%**	85	100	120	714	792	0.00000013380	85	1000	9.36
17 pdr AT gun, (76.2mm)	Firefly, AT gun	-7%	118	126	154	798	883	0.00000013480	76.2	1000	7.7
76mm M1A1 L/52	Sherman 76	**-1%**	90	91	111	709	792	0.00000013480	76	1000	7.03
76mm M3 AT gun, L/50^^, **	US AT Gun	**-13%**	82	92	113	715	792	0.00000013480	76	914.4	6.99
76.2mm F-34 L/41.5	T34/76	**-11%**	49	54	66	578	655	0.00000013480	76.2	1000	6.3
7.5cm KwK 42 L/70	Panther	**-11%**	111	123	151	827	925	0.00000013500	75	1000	6.8
7.5cm KwK 40 L/48*	Pz IV, StuG III	**-6%**	85	90	110	707	790	0.00000013500	75	1000	6.8
7.5cm Pak 40, L/48*	Ger AT Gun	**-4%**	89	92	113	715	800	0.00000013500	75	1000	6.8
7.5cm KwK 37 L/24*^	Pz IV, StuG III	**27%**	35	25	26	343	385	0.00000013905	75	1000	6.8
75mm M3	Sherman 75	-2%	60	61	74	581	650	0.00000013500	75	1000	6.8
57mm M1943 (ZIS-2) L/73^*	Sov AT gun	**-32%**	78	103	129	856	990	0.00000014000	57	1000	3.14
6 pdr AT gun, L/43, (57mm)	Brit AT Gun	**-8%**	71	77	97	734	846	0.00000014000	57	1000	3.2
57mm M1 AT gun, L/50^^	US AT Gun	**-12%**	62	69	87	737	853	0.00000014000	57	914.4	2.85
5cm PaK 38, L/60*	AT Gun, Pz III J	**-23%**	48	59	74	701	835	0.00000014400	50	1000	2.06
5cm PaK 38, L/60*	AT Gun, Pz III J	**-15%**	50	58	72	693	825	0.00000014400	50	1000	2.06
5cm KwK 38 L/42	Pz III G-J	**-10%**	36	40	50	575	685	0.00000014400	50	1000	2.06
3.7cm Pak 35/36 L/45*	Ger AT Gun	**5%**	29	27	37	634	745	0.0000001620	37	500	0.685
3.7cm Pak 36 L/45*	Ger AT Gun	**21%**	36	29	38	646	760	0.0000001620	37	500	0.685
2.8cm sPzB 41**	Ger AT Gun	-1%	46	47	67	1057	1402	0.0000001850	20	500	0.131
2.8cm sPzB 41**	Ger AT Gun	-7%	40	43	61	1053	1430	0.0000001850	20	500	0.121

* Using alternative sources of test firing data, but theoretically should be identical as the same ammunition and test conditions are stated.
** Alternative sources of test firing data, possibly with slightly different ammunition.
*^ Theoretical calculation assumes a somewhat generous 15 degree down angle on strike.
^^ Firing tests conducted at 1000 yards range, which is 914.4 metres.
^* Firing test is using APHE or APCHE.

The Coefficient Representing the Aerodynamic Resistance to the Projectile, c

The problem with c is it varies with the size of the projectile, the velocity it is travelling and the aerodynamic design of the specific projectile. Generally speaking c remains almost constant for projectiles moving at less than around 200m/s. It then rises sharply as the projectile approaches the speed of sound; at velocities from 200m/s to around 350m/s.[297] At velocities beyond around 350m/s, c progressively decreases slightly as the velocity increases.

For each calibre considered in table Pen, standard values of c have been used to take into account the air resistance variation due to the projectile size. The velocities are assumed to be over 600m/s in all cases except the German 7.5cm KwK 37 L/24 gun. As the variation in c with velocity is small, the errors introduced due to not considering c as a function of velocity are also small.

However, c as used in table Pen does not take into account the aerodynamic design of the particular projectile warhead. This is potentially a very significant source of error and would be difficult to calculate (refer below on ammunition design).

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Muzzle Velocity , v_0

The second error introducing variable, (muzzle velocity), v_0 is much more serious than c. The problem is that using the equations above requires the muzzle velocity figures to be input into the equations from the very test firing data the equations are trying to discredit! This is classic flawed logic, because it assumes the test firing data for muzzle velocity is correct and consistent while the same data provides incorrect and inconsistent data regarding penetrations. It's a good example of the old physics saying "rubbish in, rubbish out". This is particularly true in this case because, using WWII period technology, muzzle velocity was harder to measure than penetration. In fact, one of the ways to measure muzzle velocity was to test fire the weapon to get its penetration at a particular range, and then use the physics formula to calculate the muzzle velocity!

Let us take an example shown in table Pen: the German 8.8cm FlaK 18/36. This gun was probably the most famous artillery piece from WWII. The massive number of over 17 000 were produced and in August 1944 10 930 FlaK 18/36/37s were in service. [298] This gun was possibly the most extensively tested artillery piece in WWII: it was exhaustively tested by the Germans and also by the Allies who wanted to find out everything they could about it. One would therefore imagine that the muzzle velocity figures for this weapon using its standard AT ammunition were pretty well nailed down. Well depending on some very reputable sources, the 8.8cm FlaK 18/36 L/56 and the 8.8cm KwK 36 L/56 tank gun (a weapon derived directly from the 88mm Flak, firing the same AT ammunition and with identical ballistics), had a muzzle velocity figure anywhere from 773 to 820 m/s, all firing identical ammunition. [299]

Using the equations above, at 1000 metres against vertical homogenous armour, this equates to a penetration variation from 117mm to 132mm. [300] Thus, using the equations, and before we even consider other introduced errors, we already have a theoretical penetration variation (due directly to muzzle velocity variations) from 98-111mm against 30 degree sloped armour. This variation is already larger than the original penetration variation from historical test firing data, which is 100-110mm. In other words, if we are attempting to find the true penetration ability of the '88' then we have gone backwards. If this is the case for one of the most tested weapons in WWII, then how can we possibly trust muzzle velocity data any more than penetration data on the multitude of lesser tested weapon systems?

***

In order to be consistent in using the equations and apply correct scientific method, we cannot use muzzle velocities from the same test data we are attempting to supplant. We would have to calculate muzzle velocity for the particular weapon system concerned. One might initially think that calculating muzzle velocity is a relatively simple matter of establishing breech chamber pressure and calculating the acceleration of the projectile down the length of the barrel. These are the predominant factors determining muzzle velocity and will give an approximate muzzle velocity. However, breech chamber pressure figures are only available for some weapons and these are no more reliable or consistent than muzzle velocity or direct penetration measurements. In order to calculate muzzle velocity accurately (plus or minus 1% is really required) we would need to include: knowledge of the propellant chemical composition and burn efficiency, ammunition design and amount of propellant used, significant variations of force behind the projectile (the force on the projectile changes as it accelerates down the barrel due to the increase in chamber volume and the expanding gases), friction in the barrel, exact projectile mass, exact travel length down the barrel, gun breach and barrel manufacturing tolerances (i.e. the poorer the tolerances, the more gases escape down the sides of the projectile which can dramatically reduce muzzle velocity and increase projectile instability), and barrel rifling effects (this determines the spin on the projectile which affects the forces on the shell and its acceleration time).

Did I say relatively simple? It is in fact worse than calculating penetration. In short, even with the best information and computing power available, our calculated muzzle velocity and resultant calculated penetration figures are never going to be more accurate or consistent than the direct historical test firing data.

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Table Pen contains other evidence that some of the stated muzzle velocities are inaccurate. As stated, muzzle velocity is largely a function of propellant/projectile mass ratio and the barrel length. It is interesting to note that in some weapons of similar calibre, the stated muzzle velocity is higher even though the particular weapon has a shorter calibre barrel length than comparable weapons. In this case the additional muzzle velocity can only be attributable to the amount and quality of propellant used in the round. If the actual penetration figures for the shorter barrelled weapon are around 20% below the expected theoretical penetration, and the propellant/projectile mass ratio is similar to comparable guns, the weight of evidence suggests that the variation is more due to incorrectly stated muzzle velocity than mysteriously hard batches of test armour. This is even truer if the combat reports align themselves with the test results, and the particular country in question has a mixed record of producing high quality armour. Examples in Table Pen include the US 90mm M3 L/51 and the Soviet 85mm ZiS-S-53 L/54.6. Both guns are shorter in actual and calibre length than the 8.8cm KwK 36 L/56, have similar propellant/projectile mass ratios, and yet supposedly have higher muzzle velocities. The poorer test figures for the Allied guns cannot simply be attributable to the Germans using poor quality test armour or their apparent inability to measure 1000 meters and a 30 degree angle. It is far more likely that the muzzle velocities are overstated, and /or the ammunition was of inferior design and/or quality.

Additional indirect evidence of suspect muzzle velocities comes from the relatively rare cases where the historical test result is considerably higher (i.e. around 20% or more) than the theoretical penetration. Variations of a few percent could easily be attributable to varying armour quality or test procedures, but a positive variation of this magnitude infers that at least one of the underlying parameters or assumptions is incorrect. The most

probable is an underestimated muzzle velocity as its very unlikely ammunition performance using standard AP rounds would increase penetration to this degree. An example of this in table Pen is the 75 KwK 37 L/24. The test penetration data for this weapon is very consistent between sources and shows the actual penetration is around 27% greater than the calculated penetration. This is even assuming a very generous 15 degree down angle on strike to take account of the low muzzle velocity and relatively high trajectory of this weapon (i.e. a strike angle of 15 degrees is used in the calculation and not 30 degrees). A variation of this magnitude is very unlikely to be solely due to variations in test procedure or armour quality, while an increase of only 17% in the muzzle velocity estimate (i.e. an additional 67m/s) wipes out the variation between theory and practice.

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Ammunition Design

The equations (above) take no account of variations in ammunition design or the manufactured quality of standard armour piercing rounds between specific guns, or between countries. Two key assumptions are that the only difference between projectiles of the same calibre (diameter) is their mass, and that all rounds are made identically from a solid piece of homogenous metal. These are very big assumptions! It is highly probable that two identical calibre guns with the same muzzle velocities and firing the same type of ammunition (e.g. APCBC), will have dissimilar penetration figures purely due to the particular gun's ammunition design and quality.

The ammunition for a weapon is usually as carefully developed as the weapon itself, because it's part of the weapon system and cannot be separated from it. [301] This is particularly true for AT weapons and the range of AP projectiles produced to go with it. Ignoring ammunition design and quality takes no account at all of the engineering that goes into the individual gun's ammunition design, and hence ignores part of the overall weapon system. Many good guns failed, or were at least severely handicapped, because of faulty or poorly designed ammunition. [302] An Armour Piercing Capped Ballistic Capped (APCBC) round, especially with

a high explosive filler, is not a simple piece of homogenous metal moving at high velocity. Even designing and selecting material for relatively simple solid AP shot presents challenges.

Before the projectile even strikes the armour, the ballistic shape will affect penetration. The shape of the round has a direct effect on the value c in the equations. Rounds with no ballistic cap and only a much blunter piercing cap sustain considerably more velocity retardation due to air resistance, especially over longer ranges. For similar rounds with ballistic caps the individual ballistic cap design comes into play. [303] After impacting the ballistic cap collapses enabling the piercing cap to come into contact with the armour, and different piercing cap designs have different effects on armour penetration. A well designed piercing cap not only assists penetration of face hardened armour but improves performance at oblique attack angles. Even if the ballistic and piercing caps are identical, projectiles from different guns have complex and different internal structures, and are made of different quality materials.

Strong indirect evidence of the effect of ammunition size on armour penetration is present in table Pen. It appears that the variation between actual and expected penetration tends to increase as the calibre decreases. In addition, in all 13 cases where the weapon is 76.2mm calibre or less, and the strike velocity is greater than 647m/s (i.e. over supersonic velocities) , the actual penetration from test firing is less than the theoretically predicted value. For 57-50mm calibres AT weapons the variation between actual and expected penetration can be as high as 32%. This would imply that something fundamental is happening.

If all the projectiles are made of similar material, as they are in table Pen , it appears that smaller projectiles travelling at supersonic velocities are considerably less able to survive the violence of striking armour plate without shattering, compared to larger projectiles travelling at similar velocities. It is interesting to note how much more effective all the 50-57mm AT guns were when issued with various types of ‘special’ hard cored ammunition. The inferior ability of small rounds to remain intact enough to ensure at least partial armour perforation compared to larger rounds, even though they may possess the same kinetic energy at strike, is one of the two

key reasons most countries moved to larger calibre AT guns during WWII and didn't simply produce lighter and longer barrelled 50-57mm weapons. [304] The equations do take into account the increased penetration ability of small rounds due to the lower surface area of strike (i.e. small rounds have less armour to push out of the way). However the equations do not take the tendency of smaller rounds to shatter, before any armour perforation has occurred , into account. This is even before we consider any additional effects of the specific weapon's ammunition design.

Finally, an example of the possible effect of specific ammunition design and quality on anti-armour performance is shown in table Pen for the 90mm M3 L/51 gun. The very large variation between the test results and theoretical result is not easily dismissed due to inconsistent armour quality or non-identical test procedures, when one considers the following quote: "the 90mm M3 shell fired from the M36 tank destroyer and the M26 Pershing heavy tank weighed twenty four pounds and had more striking energy than the 88mm round fired from the Tiger I's gun. But since the quality of steel used in its construction was inferior to what the Germans used, its final performance fell far short of the German round". [305]

Conclusions in regards to using Historical Test Results vs. Calculated Values for Armour Penetration Figures

When viewed in isolation it is hard to draw conclusions directly from the data presented in table Pen. However, considering the laws of physics, and the experiences from WWII and the discussions above, there are some general conclusions that can be drawn.

i. There is no doubt that there are inconsistencies and variations in supposedly identical test firing data, and the causes of these variations include test armour quality and to a lesser extent varying test procedures.

ii. It is a basic failure of scientific method to assume the test firing data for muzzle velocity is correct and/or consistent, while the same data provides incorrect and/or inconsistent data regarding penetrations. In addition, accurate calculations of muzzle velocity are fraught with potential sources of error.

iii. Many weapon systems had a range of possible muzzle velocities obtained from test firing, and this was true even for a fixed ammunition type (e.g. APCBC). This in turn leads to a wide range of possible penetration values for that ammunition type. Notably, even relatively small muzzle velocity variations results in variations in theoretical penetration values comparable to any variations in the original test firing data (this applies to every weapon considered).

iv. The equations completely fail to take onto account the often dramatic effect of a specific weapon system's ammunition design or the quality of material used in its construction. Thus, comparable ammunition types, for example Armour Piercing Capped Ballistic Capped ammunition (APCBC), have a wide range of design and (manufacturing) quality factors influencing the anti-armour performance.

v. The equations do not take into account that smaller rounds made of similar material and possessing similar kinetic energy on impact, will have a higher tendency to shatter compared to larger rounds before armour perforation occurs.

In summary, the equations have got little chance of accurately predicting the complexities of ammunition design and quality on armour penetration, realistic and accurate muzzle velocities, or manufactured weapon tolerances. On the other hand the historical test firing data, even with its inconsistencies, used the actual weapons and projectiles produced in order to obtain the penetration data. The projectiles used and the manufactured weapon tolerances were automatically treated as part of the overall weapon system, and it's the functioning weapon 'system' we are interested in. In physics terminology the historical test firing data is still the only available bridge between the world of theoretical and experimental physics.

In the end it's still more accurate to rely on actual test firing data to get the most realistic picture of the 'true' relative penetration values. However, it is vital to ensure that consistent testing parameters are used (as far as possible) by cross referencing this data from as many alternative sources as possible. This is the only way to take into account the gun's overall design,

the ammunition design, and the manufacturing quality and tolerances used in the weapon system as a whole.

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[293] The British used a ‘W/R limit rule’. The W/R limit was the British rule for determining the velocity at which a 50 percent chance of obtaining a perforation occurred. A ‘W’ meant that 20% of the weight of the projectile passed through the plate or there was a hole in the plate bigger than the diameter of the projectile. A ‘R’ meant that the projectile remained lodged in the plate. T.L. Jentz, Germany’s Tiger Tanks: Tiger I & II Combat Tactics, Schiffer Publishing Ltd, Atglen, PA, 1997, p. 12.

[294] This is advocated by Niklas Zetterling in his excellent book, Normandy 1944, J.J.Fedorowicz Publishing, Winnipeg, Manitoba, Canada, 2000, pp. 404-406.

[295] k is approximately 0.182 for high quality homogenous armour and increases for lower quality armour. Ibid.

[296] To take into account a non-flat trajectory, a different set of equations is used that requires computer iterations to solve. However, for the short distances included here (around 1000m), and the high projectile velocities being considered, the loss in accuracy due to assuming a flat trajectory is negligible.

[297] At sea level and in dry air at 20 °C (68 °F), the speed of sound is approximately 343 metre per second.

[298] Purnell’s illustrated Encyclopedia of Modern Weapons and Warfare, Phoebus Publishing Co, London, 1971, Part 8, p. 158.

[299] For example in one source alone: The Encyclopedia of German Tanks of WWII, P. Chamberlain, H. Doyle, T.L. Jentz, Arms and Armour Press, London, 1978, p. 245, the 8.8cm FlaK 18 L/56 has a muzzle velocity of 800m/s. Right next to this is the 8.8cm KwK 36 L/56 tank gun with a muzzle velocity of 773m/s. These guns are both firing identical Pzgr 39 ammunition, both have identical barrel lengths, identical rifling, identical ballistics, etc, and yet the discrepancy is in two lines on the same page. Note, this is possibly the most definitive book ever published on German Armour.

Another example: J. Piekalkiewicz, The German 88 Gun in Combat, Schiffer Military History, West Chester, PA, 1992,
p. 176, states the muzzle velocity for the 88mm FlaK 18 was between 820-840 m/s, firing a 9 kg HE shell. This is not the
Pzgr 39 in the previous example. What is interesting here is that a 191 page book with 3 pages devoted to technical data, doesn’t give a fixed muzzle velocity for a single type of ammunition. It illustrates the apparent historical difficulty in determining muzzle velocity accurately.

[300] This uses k=0.182, c=0.0000001335, m=10.2kg, d=88mm, x=1000m, and the constant e=2.718281…

[301] In some cases the ammunition is not developed specifically for the weapon but a hangover from a previous weapon system. For example, the German 75mm Pzgr 39 used by the 7.5cm KwK 40 L/43 and L/48 (used on the Pz IV), is also used by the 7.5cm KwK 42 L/70 (used on the Panther). The

higher muzzle velocity of the Panther's gun is due to the longer barrel, but the warhead itself was still originally designed for lower impact velocities. P. Chamberlain, H. Doyle, T.L. Jentz, The Encyclopedia of German Tanks of WWII, Arms and Armour Press, London, 1994, pp.245 and 252.

[302] For example, in December 1941 the US produced the 3in M5 AT gun. The gun was the next generation after the 57mm M1 and at that time was considered to be capable of stopping any tank in the world. However, the initial ammunition designs were poor, which imparted mediocre AP performance. By 1944 when most of the problems had been ironed out the gun was acceptable, but by then most people (in the US Army) had lost faith in it. Purnell's illustrated Encyclopedia of Modern Weapons and Warfare, Phoebus Publishing Co, London, 1971, Part 32, p. 635.

[303] The presence of a ballistic cap actually impedes penetration slightly, but the improved ballistics performance of the round more than compensates for this.

[304] The other main reason is that heavier rounds have much greater effective range, because their velocity decrease over distance is much less. This is due to the physical law of 'conservation of linear momentum'. These reasons are also why most modern MBTs have at least a 120mm gun.

[305] M. Green, Tiger Tanks, Motorbooks International, Osceola WI, USA, 1995, p. 80. In addition various US Army combat reports indicate problems with the 90mm M3 AP ammunition.

Appendix B

Combat Aircraft versus Armour during WWII: Factors to Consider in Calculating Aircraft Relative Anti-Armour Values (AT)

The Historical Record

Modern literature on WWII is replete with accounts of devastating air strikes on tank units. There are many stories about dozens, or even hundreds, of enemy tanks being destroyed in a single day, thereby destroying or blunting an enemy armoured offensive. These accounts are particularly common in literature relating to later war ground attack aircraft, most commonly the Soviet Ilyushin II, the British Hawker Typhoon, the American Republic P-47, and the German Henschel Hs 129. All these aircraft have the distinction of being called ‘tank-busters’ and all have the reputation for being able to easily destroy any type of tank in WWII. In some cases, authors go so far as to claim an aircraft type was the ‘best antidote’ to certain tank types, e.g. the Tiger I tank’s nemesis in Normandy was apparently the rocket firing Typhoon.

Did this really happen? Today, many people think about the capabilities of modern combat aircraft when thinking about a WWII aircraft’s ‘tank busting’ ability. However WWII was an age where there were very few guided weapons and aircraft had great difficulty hitting small targets, especially if they were well protected. [306] In fact all the so called ‘tank-busters’ proved relatively ineffective against armoured ground targets (AFVs) or even small, defensively deployed, ground targets. This is despite the very exaggerated claims made by aircrew and much immediate post-war aircraft literature on the effects of air attacks on hard (i.e. armoured or fortified) ground targets. These claims were almost never ratified by corresponding after action ground reports from either the defending or attacking side’s ground forces. The following examples illustrate this occurrence, and are classic examples of how WWII stories and claims have found their way into the history books.

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If there was any campaign in WWII where conditions were perfect for airpower to demonstrate its ability to kill armour, it was in Normandy in the summer of 1944. The Allies had air supremacy (which is much more than just air superiority) and during daylight hours they could attack any target at will, with the single proviso of avoiding nasty flak concentrations. They had thousands of some of the best and most powerful ground attack aircraft available in WWII. They had virtually unlimited supplies of ammunition and fuel, and a huge amount of logistical ground support. Air bases were in easy range, targets were concentrated in a very small front line area, and the weather could not realistically have been better.

According to the RAF, the Hawker Typhoon was the most effective ground attack and tank killing aircraft in the world in 1944, which may have been true. No fewer than 26 RAF Squadrons were equipped with Typhoons by mid-1944. These aircraft operated round the clock during the Normandy campaign operating in 'cab rank' formations, literately flying above the target area in circles, waiting their turn to attack. Official RAF and USAF records claim the destruction of thousands of AFVs in Normandy. There are many examples such as:

- During Operation Goodwood (18th to 21st July) the 2nd Tactical Air Force and 9th USAAF claimed 257 and 134 tanks, respectively, as destroyed. Of these, 222 were claimed by Typhoon pilots using RPs (Rocket Projectiles). [307]
- During the German counterattack at Mortain (7th to 10th August) the 2nd Tactical Air Force and 9th USAAF claimed to have destroyed 140 and 112 tanks, respectively, as destroyed. [308]
- On a single day in August 1944, the RAF's Typhoon pilots claimed no less than 135 tanks as destroyed. [309]

So what really happened? Unfortunately for air force pilots, there is a small unit usually entitled Research and Analysis which enters a combat area once it is secured. This is and was common in most armies, and the British Army was no different. The job of The Office of Research and

Analysis was to look at the results of the tactics and weapons employed during the battle in order to determine their effectiveness (with the objective of improving future tactics and weapons).

In Normandy they found that the various air forces' claims did not match the reality at all. In the Goodwood area a total of 456 heavily armoured vehicles were counted, and 301 were examined in detail. They found only 10 could be attributed to Typhoons using RPs (less than 3% of those claimed). [310] Even worse, only 3 out of 87 APCs examined could be attributed to air lunched RPs. The story at Mortain was even worse. It turns out that only 177 German tanks and assault guns participated in the attack, which is 75 less tanks than claimed as destroyed! Of these 177 tanks, only 46 were lost and only nine were lost to aircraft attack. [311] This is again around 4% of those claimed. When the results of the various Normandy operations are compiled, it turns out that barely 100 German tanks were lost in the entire campaign from hits by aircraft launched ordnance. [312] Thus on a single day in August 1944 the RAF claimed 35% more tanks destroyed than the total number of German tanks lost directly to air attack in the entire campaign!

Considering the Germans lost around 1500 tanks, tank destroyers and assault guns in the Normandy campaign, less than 7% were lost directly to air attack. [313] The greatest contributor to the great myth regarding the ability of WWII aircraft to kill tanks was, and still is, directly the result of the pilot's massively exaggerated kill claims. The Hawker Typhoon with its cannon and up to eight rockets was (and still is in much literature) hailed as the best weapon to stop the German Tiger I tank, and has been credited with destroying dozens of these tanks during the Normandy campaign. According to the most current definitive works only 13 Tiger tanks were destroyed by direct air attack in the entire campaign. [314] Of these, 7 Tigers were lost on 18th July 1944 to massive carpet bombing by high altitude heavy bombers, preceding Operation Goodwood. [315] Thus, at most, only 6 Tigers were actually destroyed by fighter bombers in the entire Normandy campaign. It turns out the best Tiger stopper was easily the British Army's 17pdr AT gun, with the Typhoon well down on the list.

Indeed it appears that air attacks on tank formations protected by flak were more dangerous for the aircraft than the tanks. The 2nd Tactical Air Force lost 829 aircraft in Normandy while the 9th USAAF lost 897. [316] These losses, which ironically exceed total German tank losses in the Normandy campaign, would be almost all fighter-bombers. Altogether 4 101 Allied aircraft and 16 714 aircrew were lost over the battlefield or in support of the Normandy campaign. [317]

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According to the Soviets (and in much current literature) the Ilyushin IL-2 'Shturmovik' was the most 'successful' ground attack aircraft in WWII. [318] The most numerous aircraft in WWII (with at least 36 136 produced) [319] , it is claimed the IL-2 was responsible for the destruction of huge numbers of German tanks. Let us consider some examples of published 'results' for the IL-2 during the battle of Kursk, where it is claimed the IL-2 destroyed many hundreds of German tanks.

1. On 7th July 1943, in one 20 minute period it has been claimed IL-2s destroyed 70 tanks of the 9th Panzer Division. [320]

   It actually turns out that close to the start of the battle on 1st July 1943, 9th Panzer Division had only one tank battalion present (the II. /Pz Regt 33) with only 83 tanks and assault guns of all types in the Division. [321] 9th Panzer Division doesn't record any such loss in July (it registers an air-attack referred to as heavy strafing), and 9th Panzer Division continued in action for over three months after this so called 'devastating attack', with most of its initial tanks still intact. [322]

2. During the battle of Kursk, the VVS IL-2s claimed the destruction of no less than 270 tanks (and 2,000 men) in a period of just two hours against the 3rd Panzer Division. [323]

   On 1st July the 3rd Panzer Division's 6th Panzer Regiment had only 90 tanks, 180 less than claimed as destroyed! [324] On 11th July (well after the Kursk battle) the 3rd Panzer Division still had 41 operational tanks.[325] The 3rd Panzer Division continued fighting throughout July,

mostly with 48th Panzer Corps. It did not record any extraordinary losses to air attack throughout this period. As with the other panzer divisions at Kursk, the large majority of 3rd Panzer Division's tank losses were due to dug in Soviet AT guns and tanks.

3. Perhaps the most extraordinary claim by the VVS's IL-2s, is that over a period of four hours (during the battle of Kursk) they destroyed 240 tanks and in the process virtually wiped out the 17th Panzer Division.

   On 1st July the 17th Panzer Division had only one tank battalion (the II. /Pz Rgt 39) with a grand total of only 67 tanks. [326] This time only 173 less than claimed destroyed by the VVS! The 17th Panzer Division was not even in the main attack sector for the Kursk battle, but further south with 1st Panzer Army's 24th Panzer Corps. The 17th Panzer did not register any abnormal losses due to aircraft in the summer of 1943, and retreated westwards with Army Group South later in the year still intact.

In fact total German tank losses in Operation Citadel amounted to 1,612 tanks and assault guns damaged and 323 totally destroyed, the vast majority to Soviet AT guns and AFVs. [327] Where are the many hundreds destroyed by IL-2's? It appears the RAF and VVS vied for the title for 'most tank kill over-claims in WWII'.

In addition it is difficult to find any first-hand accounts by German Panzer crews on the Eastern Front describing anything more than the occasional loss to direct air attack. The vast majority, around 95%, of tank losses are due to enemy AT guns, tanks, mines, artillery, and infantry assault, or simply abandoned as operational losses. Total German fully tracked AFV (total) losses on the East Front from 1941 to 1945 amounted to approximately 32 800 AFVs. At most 7% of these were destroyed by direct air attack, which amounts to approximately 2 300 German fully tracked AFV lost to direct air attack, a portion of which were lost to other aircraft types such as the Petlyakov Pe-2. From 22nd June 1941 to war's end, 23 600 Il-2 and Il-10 ground attack aircraft were irrecoverably lost. [328] Whatever these aircraft were doing to pay such a high price it wasn't destroying German tanks. If that was there primary target, then over 10 Il-2s

and Il-10s were irrecoverably lost for every German fully tracked AFV that was completely destroyed by direct air attack on the East Front during WWII.

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In July 1943 the German Citadel Offensive (battle of Kursk) was supported by several types of apparently highly effective ground attack aircraft, two of which were specialist tank killing machines. The first was the Henschel 129B-1/2. Made in modest numbers (only 870 of all types) it was specifically designed for the anti-tank and close support mission. The second was the Ju87G-1, armed with two 37mm cannon and also specifically designed to kill armour. These aircraft, along with Fw-190Fs, were first employed en masse in the *Schlachtgeschwader* units supporting Operation Citadel.

These aircraft are credited with 'wreaking havoc amongst Soviet armour' and the destruction of hundreds of Soviet tanks during this battle. On 8th July 1943, Hs 129s are credited with destroying 50 T-34s in the 2nd Guards Tank Corps in less than an hour. [329] There is evidence that 2nd Guards Tank Corps took heavy casualties on 8th July, but 50 tanks appears to exceed their total losses from all causes. In fact total Soviet tank losses in Operation Citadel amounted to at least 1,614 tanks totally destroyed; the vast majority to German tanks and assault guns. [330] Further detailed research has shown air power only accounted for around 5% of Soviet tanks destroyed in the battle of Kursk, which equates to around 80 tanks. [331] Again, even if this is a low estimate, where are the hundreds of tanks destroyed by German ground attack aircraft?

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Factors to consider in calculating Aircraft Relative Anti-Armour Values (AT)

AFVs, particularly medium or heavy tanks, were probably the most difficult targets for aircraft to attack in WWII. Given the more realistic historical assessments detailed (above) for Normandy and Kursk, a more

objective analysis shows why aircraft attempting to attack armour in WWII faced several major hurdles.

1. During WWII, aircraft with unguided weapons were relatively inaccurate. To a lesser extent this is the case even today and there is no comparison with modern combat aircraft with guided weapons. Against ‘soft’ targets this was not as critical because bombs and rockets deployed by WWII aircraft were area weapons. Even so, small soft targets such as entrenched AT guns were difficult for WWII aircraft to destroy. Small pinpoint and ‘hard’ targets, like a moving tank, were very hard to kill. This was because a tank generally required a direct hit with an AT weapon, or a near miss with a very large air launched weapon, to destroy it. Even much larger moving targets such as ships were difficult to hit by modern standards. This inaccuracy stems from the nature of aircraft and the state of guided weapon technology at that time. In practical terms this meant that for an average fighter-bomber conducting a strafing attack, the tank remained in the gun sight for approximately a 10th of a second! Even if the pilot was to point his aircraft straight at the tank, a difficult and dangerous manoeuvre against a heavily protected target like a tank spearhead, he would have had at most a few seconds to aim his cannon, MGs, rockets or bombs.

2. Land based vehicles could carry enough ammunition to sustain approximately an hour of combat, but aircraft could not. Aircraft carried very limited ammunition for their permanently mounted weapons such as cannon, and obviously carried relatively limited numbers of individual air launched weapons i.e. bombs and rockets. This meant they could only attack the target for a very limited time compared to land based weapon systems. Even late in WWII, aircraft only carried sufficient ammunition for 1-4 passes on the target.

3. Most aircraft mounted automatic weapons were not designed for sustained fire. Apart from ammunition considerations, these weapons quickly overheated and would likely jam if fired for more than a few seconds at a time. Most often they were fired in shorter bursts suited to air to air combat.

4. Aircraft mounted weapons spent much less time in service (i.e. actually exerting their lethality) compared to ground based weapons, due to overall aircraft serviceability. Minor aircraft malfunctions were much more likely to remove the weapon from combat operations compared to similar malfunctions in ground based weapons. This is in addition to the weapon's Reliability Factor (RL), which only considers the inherent reliability of the weapon itself.

5. Aircraft were not suited to carry large calibre and high muzzle velocity AT weapons. This was due to the weight of these weapons with more than a few rounds of ammunition and the very severe recoil stresses placed on the airframe. The largest AT weapons placed on WWII aircraft were the 75mm Pak40L guns on the Henschel Hs 129B-3 and the Junkers Ju 88P-1. Neither aircraft was particularly successful with the 'monster gun' really proving too much for the airframes. The Hs 129B-1/2 with 30-37mm AT guns was more successful, while Ju 88P remained one of the few unsuccessful developments of the basic Ju 88 design. It is worth mentioning the relatively successful Ju87G-1, armed with two 37mm BK (Flak 18) AT guns. This modification provided the obsolescent Ju 87 with a new lease of life late in WWII. It is interesting to note that the Hs 129B-3 carried only four 75mm rounds while the Ju87G-1 carried only 12 37mm rounds. Good examples of the very limited amount of ammunition carried for aircraft mounted weapons (point 2. above).

   During WWII, the large majority of aircraft which attacked tanks with aircraft mounted weapons used 20mm cannon or simply HMGs. These include aircraft such as the Supermarine Spitfire, Hawker Typhoon, Hawker Tempest, De Havilland Mosquito, most Ilyushin Il-2s and Il-10s (some had 37mm cannon), Yakovlev Yak-7/9, Petlyakov Pe-2/3bis, Lockheed P38 Lightning, North American P51 Mustang and Republic P47 Thunderbolt. The average 20mm cannon with standard ammunition had great difficulty penetrating the 12-15mm top armour on the Pz IV H or the 16mm top armour on the Panther, and almost no chance against the 25mm top armour on the Tiger I, even if they managed to hit them! The reader should also bear in mind that the strike angle of cannon shells on the top of AFVs was usually in the

region of 40 to 70 degrees because aircraft could not attack vertically downwards (the Ju 87 came closest to this ideal attack angle, which also dramatically increases the accuracy of any air launched ordnance). In general 20mm cannon only inflicted superficial damage on even light tanks, with the most severe damage being penetrations through the top engine grill covers and damage to the engines. Unless the battlefield situation dictated that these tanks became operational total losses (e.g., abandoned due to retreat), then they were usually quickly repaired and returned to service.

The lack of a suitable anti-tank armament meant all these aircraft had to rely on much less accurate air launched weapons (i.e. rockets and bombs) to kill late war German tanks. Late war rockets and heavy bombs were capable of destroying a medium tank, but were considerably less accurate than the already inaccurate fire from cannon and MGs. Against a Panther or Tiger tank, nothing short of a direct hit was going to have much chance of destroying them.

6. AFVs and tanks were usually found in forward combat units and 'spearhead' attack formations. These units often had light and medium flak units protecting them which consisted of 20-37mm mobile flak guns. Even in 1941 during Operation Barbarossa, German panzer divisions had integral light flak units with the panzer regiments. This made tank targets extremely dangerous to attack compared to most other ground targets. In addition, aircraft attacking tanks were required to attack at low level, well in reach of light flak guns. The flak also meant fighter-bombers were less able to fly using a nice straight attack approach, and were often thrown about by exploding flak shells, further reducing their accuracy. Indeed it seems that air attacks on tanks protected by flak were more dangerous to the aircraft than the tanks. The 1 726 fighter-bombers lost from the 2nd Tactical Air Force and the 9th United States Air Force over Normandy in 1944 is testament to how lethal light flak can be. [332]

7. Weather and visibility were major considerations for all air operations. This was especially true for aircraft attempting low level attacks against armour without any form of all-weather equipment enjoyed by modern day combat aircraft.

***

In calculating the Aircrafts Relative Anti-Armour Values (AT), factors 1, 2, 3 and 4 above are included in calculating the aircraft's Weapon Combat Power Coefficients (WCPCs). The factors of most interest in the WCPC calculations are the Accuracy (A) and Aircraft Mounted Weapon Effect (AE). Refer to Part II 2. (Calculating Individual Weapon Combat Power Coefficients (WCPCs)), and Part II 2. 1) e. and h. (Accuracy (A) and Aircraft Mounted Weapon Effect (AE) factors). Factors 6 and 7 above are tactical and operational considerations, and are implemented in whatever combat model is being used to simulate air to ground combat. This leaves factor 5 above, which is the anti-armour performance (i.e. armour penetration) of the air mounted or air launched weapon being used.

For aircraft mounted weapons , the 'armour penetration' is the ability of the weapon to penetrate homogenous armour plate sloped at 30 degrees from vertical at 1000 metres range, using its most common AT round. Refer to Appendix A for a more on determining armour penetration figures from historical test results and calculated values. Aircraft mounted weapons are considerably more accurate than air launched weapons but suffer the full penalty of the Aircraft Mounted Weapon Effect (AE) factor. However in the calculation of the aircraft's Relative Anti-Armour Value (AT), the armour penetration value established above is multiplied by 3. This is because a large proportion of hits against AFVs will be hitting the thinner top armour, and on average top armour would be around a third as strong as frontal and side armour on most AFVs.

Therefore (as detailed in Part II 3. 4) b.), **for aircraft with stronger aircraft mounted AT weapons**, the Relative Anti-Armour Value (AT) is given by,

$$AT_{Aircraft} = Roundup\left(\left(PEN_{30\ \deg/\ 1000\ m} * 3 * A * AE\right)/\ 5\right)$$

where: $PEN_{30deg/1000m}$ is the penetration ability of the most powerful aircraft mounted weapon, A is the

Accuracy (A) factor and AE is the Aircraft Mounted Weapon Effect (AE) factor used in calculating the WCPC for the aircraft mounted weapon being considered.

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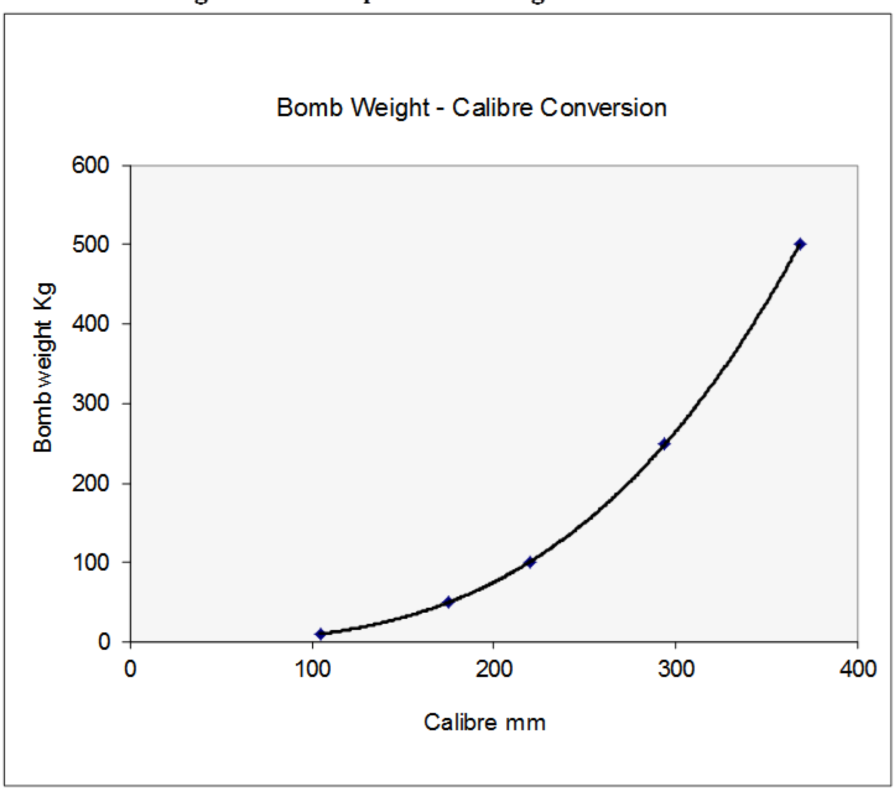
For aircraft launched weapons , the ‘armour penetration’ is more difficult to establish. We will consider unguided rockets and bombs separately as the two principal aircraft launched weapons in WWII.

Aircraft bombs are essentially area weapons and as such have large Potential Targets per Strike (PTS) factors. When calculating the PTS factor for bombs we use Graph BW, which shows the relationship of air launched bomb weight versus average weapon calibre. Refer to Part II 2. 1) b. (Number of Potential Targets per Strike (PTS)).

Graph BW

Average Relationship of Bomb Weight to Calibre.

PTS	Calibre mm (x)	Equiv Bomb Weight Kg (y)
1375	105	10
4358	175	50
6035	220	100
6970	294	250
7802	368	500



From this we can see that even a relatively small 50kg bomb is approximately equivalent to a 175mm calibre artillery round and a 100kg bomb is equivalent to a 220mm calibre artillery round. Thus, even a relatively small bomb with a delayed fuse and dropped from medium altitude is capable of penetrating the top armour of most tanks with a direct hit. For all intents and purposes, it doesn't matter whether the bomb is a 500kg bomb or a 100kg bomb: a direct hit would almost certainly destroy most tanks. However, very few tanks in WWII sustained a direct bomb hit while a great many would have sustained near misses.

The problem is that if the same bombs near-miss the tank, most of the explosive force is dissipated away from the tank and any shrapnel would most likely hit the sides, front and rear of the tank (i.e. the most well protected parts). It is worth noting that a fighter-bomber pilot glancing backwards at the resultant explosion near (or around) the tank would probably claim it as a kill. Obviously there is a huge difference in the explosive force and shrapnel between a heavy 500kg and a light 50kg bomb. The question is how close to the tank does the bomb need to land to inflict serious or fatal damage? As the bomb gets larger, the 'safe' distance the tank has before the bomb inflicts serious damage gets shorter. Naturally the tougher and heavier the tank's protection, the closer the bombs can land without inflicting severe damage.

In general the energy in the compression wave from an explosion dissipates in proportion to the square of the distance from the explosion centre. Thus a tank standing 10 meters from the centre of an explosion would experience around 4 times the force it would if it were 20 meters from the centre of the explosion. As the bomb get larger its lethal anti-tank radius increases, and this translates into an armour penetration rating. It should be understood that this 'anti-tank radius' (and hence armour penetration rating) increases much more slowly than the 'lethal anti-personnel radius' for two main reasons. Firstly, personnel protected by even light armour are much better protected from the effects of a blast compression wave. The AFV absorbs most of the blast energy (even the thinnest of armour is far better than human tissue), and as the blast effects diminish with the square of the distance, AFVs and their crews very quickly become 'safe'. Secondly, the effects of shrapnel and explosion debris <u>do not</u>

dissipate with the square of the distance. This means that personnel are vulnerable to even the smallest pieces of shrapnel over considerable distances. AFVs on the other hand are far less prone to serious damage from shrapnel and flying debris, and even light AFVs (such as armoured cars and APCs) can withstand quite heavy shrapnel damage. Heavier tanks with 50mm or more of base armour would only worry about shrapnel with immense kinetic energy (deadly as it is to personnel at most distances, shrapnel rarely has the kinetic energy or the ballistic stability of an AP round).

10kg and 50kg bombs, the approximate equivalent of a 105mm and 175mm artillery round, would essentially need to hit most WWII tanks to destroy them. Thus their armour penetration rating is 5 and 10mm respectively; the typical top armour on the average WWII tank. At the top end, a 500kg bomb has a 'near miss armour penetration' value of approximately 40mm. To put it another way, a 500kg bomb landing reasonably close to a tank will have the destructive effect on the tank equivalent to being hit by an AT round capable of penetrating 40mm of armour. The term 'near miss' is used because a 500kg bomb dropped from medium to high altitude can actually penetrate battleship deck armour with a direct hit, i.e. the actual armour penetration is much higher than our 'near miss' armour penetration value.

Therefore, for aircraft launched bombs, the 'armour penetration' against AFVs is taken from the table below:

Air Launched Weapon vs. Equivalent Anti-Armour Performance			
Air launched rockets, by year of service	Air launched, free-fall bomb weight, kg	Equivalent armour penetration, mm	Radius of bomb PTS area, m
	10	5	21
1940	50	10	37
1941	100	20	44
1942-1943	250	30	47
1944-1945	500+	40	50+

The radius of the bomb PTS area is taken from our OCPC methodology calculating the bomb's WCPC. It is effectively the lethal radius of the weapon against personnel, and is simply used for comparison to the 'near miss armour penetration' (PEN) value.

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Aircraft launched rockets in WWII were essentially an attempt to improve the accuracy of air launched weapons and enable a degree of 'standoff' from the target. Early war aircraft rockets carried relatively small high explosive (HE) warheads, which were not specifically designed for armour penetration. In 1941 the Soviet Ilyushin Il-2 typically carried 8 RS-82 82mm rockets. The RS-82 rockets were based on the 82mm M-8 rockets used in the BM-8-36 ground based system, with a rocket weight of 8kg and explosive content of 0.5kg. These rockets were known for their inaccuracy when used as ground based weapons, but an aircraft using them at close range was still more accurate than using bombs. However, a 0.5 kg warhead equates to PTS values similar to typical 45mm HE warhead. Without any adaptation to penetrating armour these rockets had a relatively low penetration rating. In addition, such a small warhead demanded a direct hit to have any chance of destroying even a light tank, and even then total destruction was unlikely. This is directly at odds with the popular image of Il-2 rockets destroying heavy armour. [333]

As the war progressed aircraft rockets improved, and in some cases hollow (also called shaped or HEAT) charge warheads were used which increased the armour penetration. By 1944 the Hawker Typhoon was carrying 8x 76.2mm 27 kg rockets. Test trials against captured Panther tanks showed these rockets were capable of defeating the Panther A's side turret and superstructure armour of 40-45mm, but could not penetrate the Panther's frontal armour at 80mm. [334] As an aside it is worth noting that the Tiger I had 80mm of armour on its turret and superstructure sides and rear. Regardless, throughout the war rockets needed to achieve a direct hit to destroy or even damage most tanks, and their accuracy never really improved much. The trials on training grounds in England revealed that fighter-bombers attacking with salvoes of up to 8 rockets at a time, still only

had at most a 4% chance of hitting a tank. This was without defending anti-aircraft fire and attacking a stationary target in an open field. [335]

For aircraft launched rockets, the ‘armour penetration’ is deduced from the table above. However, the accuracy rating does not improve significantly from 1941 to 1945.

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Therefore (as detailed in Part II 3. 4) b.), **for aircraft with stronger aircraft launched AT weapons**, the Relative Anti-Armour Value (AT) is given by,

$$AT_{Aircraft} = Roundup\left(\left(PEN_{Air\ L\ Wpns} * A * AE\right)/5\right)$$

where: $PEN_{Air\ LWpns}$ is the penetration ability of the most powerful aircraft launched weapon carried,

deduced from the table above, A is the Accuracy (A) factor and AE is the Aircraft Mounted Weapon Effect (AE) factor used in calculating the WCPC for the aircraft launched weapon being considered. Note, for aircraft launched weapons the AE factor is normally (but not always) = 1.

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[306] The only air launched guided weapons in WWII of any significance were German. The most successful of these were the radio controlled anti-shipping missiles such as the Fritz X.

[307] P. Moore, Operation Goodwood, July 1944; A Corridor of Death, Helion & Company Ltd, Solihull, UK, 2007, p. 171.

[308] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 38.

[309] S. Wilson, Aircraft of WWII, Aerospace Publications Pty ltd, Fyshwick ACT, Australia, 1998, p. 85.

[310] P. Moore, Operation Goodwood, July 1944; A Corridor of Death, Helion & Company Ltd, Solihull, UK, 2007, p. 171.

[311] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, pp. 38 and 52.

[312] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 38.

[313] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 83.

[314] C. W. Wilbeck, Sledgehammers, The Aberjona Press, Bedford, Pennsylvania, 2004, p. 131, table 4. This low figure is verified by the combat records of the three Tiger battalions that fought in Normandy; detailed in W. Schneider, Tigers in Combat I, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 1994, pp. 164-166 (503rd Heavy Tank Battalion), and W. Schneider, Tigers in Combat II, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 1998, pp. 256-262 (101st Heavy SS Tank Battalion) and pp. 327-333 (102nd Heavy SS Tank Battalion).

[315] Ibid.

[316] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 38. Note, these losses include losses sustained attacking vital rear areas including railroads and bridges, where the real damage to the German effort in Normandy was done. Nevertheless, the majority of Fighter Bomber losses were due to flak protecting combat units.

[317] S. Badsey, Normandy 1944, Osprey Military Campaign Series, Reed International Books Ltd, London, 1990, p. 85.

[318] If 'success' is measured by the amount of enemy material and personnel destroyed (including tanks, ships, guns, trucks, bunkers, pillboxes, other fortified positions, etc) divided by the number of aircraft fielded and subsequently lost, then the most successful ground attack aircraft of WWII was (by an order of magnitude) the German Ju 87.

[319] Does not include the similar but much improved Il-10 produced from October 1944, and in action by February 1945.

[320] F. Crosby, The Complete Guide to Fighters and Bombers of the World, Anness Publishing Ltd-Hermes House, London, 2006, p. 365. Also, M. Healy, Kursk 1943, Osprey Military Campaign Series, Reed International Books Ltd, London, 1993, p. 56.

[321] D. M. Glantz, J.M. House, The Battle of Kursk, Ian Allan Publishing Ltd, Surrey, UK, 1999, p. 349.

[322] T. L. Jentz, Panzer Truppen: Volume 2, The Complete Guide To The Creation And Combat Deployment of Germany's Tank Force 1943-1945, Schiffer Military History, Atglen, PA, 1996, pp. 74-101.

[323] F. Crosby, The Complete Guide to Fighters and Bombers of WWII, Anness Publishing Ltd-Hermes House, London, 2006, p. 365.

[324] D. M. Glantz, J.M. House, The Battle of Kursk, Ian Allan Publishing Ltd, Surrey, UK, 1999, p. 350.

[325] D. M. Glantz, J.M. House, The Battle of Kursk, Ian Allan Publishing Ltd, Surrey, UK, 1999, p. 353.

[326] T. L. Jentz, Panzer Truppen, Volume 2, The Complete Guide to the Creation and Combat Deployment of Germany's Tank Force 1943-1945, Schiffer Military History, Atglen, PA, 1996, p. 80.

[327] D. M. Glantz, J.M. House, The Battle of Kursk, Ian Allan Publishing Ltd, Surrey, UK, 1999, p. 276.

[328] G. F. Krivosheev, Soviet Casualties and Combat Losses in the Twentieth Century, Greenhill Books, London, 1997, pp. 254 and 255. Krivosheev lists only 100 Ground attack aircraft available on 22nd June 41, so these are all IL-2s. Pe-2s are listed as bombers, and fighter-bombers are listed as fighters. Krivosheev also claims 11 200 Il-2s were non-combat losses, a figure almost impossible to reconcile with other WWII air forces' non-combat losses.

[329] M. Healy, Kursk 1943, Osprey Military Campaign Series, Reed International Books Ltd, London, 1993, p. 66.

[330] D. M. Glantz, J.M. House, The Battle of Kursk, Ian Allan Publishing Ltd, Surrey, UK, 1999, p. 276. According to Glantz and House, these are admitted Soviet tanks totally destroyed but the actual number is probably higher. In addition a similar number were probably recovered as repairable.

[331] Tank Forces in Defense of the Kursk Bridgehead, Journal of Slavic Military Studies, Frank Cass, London, Volume 7,
No 1, March 1994, p. 114.

[332] N. Zetterling, Normandy 1944, J.J. Fedorowicz Publishing Inc, Winnipeg, Canada, 2000, p. 38. The vast majority of these aircraft were destroyed by flak, as the Allies enjoyed air supremacy during the Normandy Campaign.

[333] To date, this author has not found any German reports indicating any panzer total losses to rocket armed aircraft in 1941.

[334] I. Gooderson, Allied Fighter-Bombers Versus German Armour in North-West Europe 1944-1945: Myths and Realities, Journal of Strategic Studies, Volume 14, Issue 2, June 1991, p. 212.

[335] I. Gooderson, Allied Fighter-Bombers Versus German Armour in North-West Europe 1944-1945: Myths and Realities, Journal of Strategic Studies, Volume 14, Issue 2, June 1991, p. 212.

Appendix C

Table of Contents, Volume IIA: The German Armed Forces (Wehrmacht), Mobilisation and War Economy from June to December 1941

The following is the Table of Contents for Volume IIA, scheduled to be published in 2013. It is subject to minor change, although any changes will comprise additional content.

***

Introduction

1. Overview of the Structure and Terms Used in the German Fully Integrated Land and Air Resource Model (FILARM)

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    iv. 2.8cm *schwere Panzerbuchse* 41 (s.Pzb 41)
  c. Mortars
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    ii. Granatwerfer 34 (GrW 34)
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g. Panzerkampfwagen 35-S 739(f)

h. Panzerkampfwagen 38-H 735(f)

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a. Kleine Panzerbefehlswagen

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17) Fighter Bomber Aircraft
  a. Messerschmitt Bf 110

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ii. Army HQs

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vii. Motorised Heavy 210mm Howitzer Battalions (Type 1 and 2)

viii. Motorised Heavy 210mm Gun Battalions

ix. Motorised Heavy 240mm Howitzer Battalions

x. Motorised Heavy 240mm Gun Battalions

xi. Motorised Super Heavy Howitzer Battalions

xii. German Railroad Artillery Battalions and Batteries

xiii. Coastal Artillery Battalions and Batteries

xiv. Horse-Drawn Corps and Miscellaneous Artillery Units

d. Rocket Artillery (*Nebelwerfer*) Units

i. Motorised Special Rocket Launcher Regiment HQs

ii. Motorised Rocket Launcher Regiments

iii. Motorised Rocket Launcher Battalions

iv. Motorised Decontamination Battalions

e. Anti-Tank Units

i. Motorised Anti-Tank Battalions

ii. Self-Propelled Heavy Anti-Tank Companies

f. Army Anti-Aircraft (Flak) Units

i. Motorised Army Anti-Aircraft Battalions

ii. Mechanised Army Light Anti-Aircraft Companies

iii. Mechanised Army Light Anti-Aircraft Battalions

g. Machine Gun Battalions

h. Combat Engineer (*Pionier)* and Engineer Units

i. Motorised Special Engineer Regiment HQs

ii. Motorised Combat Engineer (*Pionier)* Battalions

iii. Combat Engineer (*Pionier*) Battalions

iv. Motorised Engineer Bridge Construction Battalions

v. Engineer Bridge Construction Battalions

vi. Motorised Assault Boat Companies

vii. Motorised Type B Bridge Columns

viii. Separate Bridge Columns: Type (A-T)

ix. Armoured Mine Clearing Battalion

i. Army Construction Units

i. Army Construction HQs

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Appendix D

Table of Contents, Volume IIB: The German Armed Forces (Wehrmacht), Mobilisation and War Economy from June to December 1941

The following is the Table of Contents for Volume IIB, scheduled to be published in 2013. It is subject to change, although any changes will comprise additional content.

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iv. Norway Army, *Befehlsstelle Finnland* (East Front only)

v. OKH Reserves

vi. Total, East Front

b. The German Army, Waffen SS, Luftwaffe Ground Forces and Naval Coastal Artillery, Deployed (D) in the Western Fronts and the Replacement Army from 22nd June to 4th July 1941

i. Norway Army (Norway Occupation Duties)

ii. Army Group D (France-Low Countries)

iii. 12th Army (Yugoslavia-Serbia-Greece-Crete)

iv. Deutsches Afrika Corps (D.A.K) (North Africa)

v. Germany and the Remainder of Occupied Europe, and the Replacement Army

c. The Total German Army, Waffen SS, Luftwaffe Ground Forces and Naval Coastal Artillery Deployed (D) in the Reich from 22nd June to 4th July 1941

d. The Rear Area Transport Available for Supply Distribution from 22nd June to 4th July 1941

2) The Total Available Personnel and Equipment in the Reich on 1st June 1941

a. Review of Available Small Arms and Other Infantry Weapons

b. Review of Available Anti-Tank Weapons

c. Review of Available Artillery Pieces

d. Review of Available Anti-Aircraft Weapons

e. Review of Available Tanks and other AFVs

f. Review of Available Motor Vehicles and Other Transport Types

g. Review of Available Wehrmacht Personnel

3) The Proportion of Total Available Resources which were in a Deployed (D) State in the Reich from 22nd June to 4th July 1941

4. German Mobilisation After 22nd June 1941: the Actual Strength of German Land Combat Units

Mobilised from 22nd June to 31st December 1941

1) Definition of Deployed (D), Mobilised and Deployed (MD), and Mobilised and Not Deployed (MND) in the German FILARM Model
2) German Land Combat Units Mobilised from 22nd June to 31st December 1941
   a. The German Tank MD and MND Matrix
3) The Total Resources Allocated to Newly Mobilised Combat Units from 22nd June to 31st December 1941
   a. Rear Area Transport Available for Supply Distribution from 22nd June to 31st December 1941
4) The Total Resources in the Reich that were Available for Use by Newly Mobilised Units from 22nd June to 31st December 1941
   a. Total Available Resources in the Reich Unallocated to Deployed (D) Units from 22nd June to 4th July 1941
   b. New Resources Produced and Received in the Reich from June to 31st December 1941
      i. Small Arms and Other Infantry Weapons
      ii. Anti-Tank Weapons
      iii. Artillery Pieces
      iv. Anti-Aircraft Weapons
      v. Tanks and other AFVs
      vi. Motor Vehicles and Other Transport Types
      vii. Newly Conscripted Wehrmacht Personnel
5) Resources Unallocated to any Deployed (D), MD or MND Units in 1941
6) The Proportion of Total Available Resources Allocated to Deployed (D) and Newly Mobilised Units in 1941

3) The Actual Strength of German Naval Units in the Baltic during 1941

4) A History of German Naval Operations in the Baltic: June to December 1941

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Appendix E

Table of Contents, Volume IIIA: The Soviet Armed Forces, Mobilisation and War Economy from June to December 1941

The following is the Table of Contents for Volume IIIA, scheduled to be published in 2013-14. It is subject to change, although any changes will comprise additional content.

***

3) Red Army Cavalry Units
   a. A Brief History of Soviet Pre-War Cavalry Forces
   b. Cavalry Divisions 22nd June 1941
   c. Mountain Cavalry Divisions, 22nd June 1941
   d. Cavalry Divisions, 6th July 1941
4) Red Army Mountain Units
   a. A Brief History of Soviet Pre-War Mountain Forces
   b. Mountain Rifle Divisions, 22nd June 1941
5) Red Army Airborne Units
   a. A Brief History of Soviet Pre-War Airborne Forces
   b. Soviet Airborne Brigades, April 1941
   c. Soviet Airborne Brigades, September 1941
6) Soviet Naval Ground Combat Units
   a. Soviet Naval Infantry Brigades, 22nd June 1941
   b. Soviet Naval Rifle Brigades, 18th October 1941
7) NKVD Combat Units
   a. NKVD Border Guard Forces
      i. NKVD Border Guard Detachments/Units, 22nd June 1941
      ii. NKVD Border Regiments, Post 22nd June 1941
   b. NKVD Internal Guard Forces
      i. NKVD Rail Security Divisions and Regiments, 22nd June 1941
      ii. NKVD Security or Rifle Brigade
      iii. NKVD Armoured Trains
   c. NKVD Tactical Forces
      i. NKVD Motorised Divisions, 1941
      ii. NKVD Rifle Divisions, 1941
8) Soviet Militia Units
   a. Militia Rifle Divisions, 1941
   b. Moscow Militia Rifle Divisions, 1941
   c. Militia Fighter Battalions
9) Red Army Corps, Army and Front Level Units
   a. Red Army Corps and Army Level Artillery Units

        i. Corps Artillery Regiments
        ii. RVGK Cannon and Howitzer Regiments
        iii. RVGK Super Heavy Howitzer Regiments, (BM)
        iv. RVGK High Power Artillery Battalions, (OM)
        v. RVGK Mortar Battalions
        vi. RVGK (Army) Artillery Regiments, September 1941
        vii. RVGK Rocket Artillery Regiments and Battalions

    b. Red Army Corps and Army Level Anti-Tank Units

        i. RVGK Anti-Tank Brigades, April 1941
        ii. Anti-Tank Regiments, July-November 1941

    c. Red Army Corps and Army Level Anti-Aircraft Units

        i. Army Anti-Aircraft Battalions

    d. Red Army Corps and Army Level Engineer Units

        i. Engineering Regiments and Battalions, June 1941
        ii. Pontoon Bridge Regiments and Battalions, June 1941
        iii. Army Construction Battalions

    e. Soviet Headquarter (HQ) Units

        i. Rifle Corps HQs
        ii. Mechanised Corps HQs
        iii. Cavalry Corps HQs
        iv. Airborne Corps HQs
        v. Army HQs
        vi. Front HQs
        vii. PVO Air Defence Corps HQs

10) Soviet Strategic Defence Ground Forces

    a. PVO-strany, National Air Defence Ground Units
    b. Fortified Sectors or Regions
    c. Coastal Artillery

11) Railroad Artillery and Armoured Trains

    a. Railroad Artillery
    b. Armoured Trains

12) Review of the Authorised Sizes of Soviet Divisions and Brigades, from 22nd June to 31st December 1941

a. Pre-war Divisions and Brigades

b. Post-June 1941 divisions and brigades

4. The Order of Battle (OOB) of Soviet Land Combat Units on 22nd June 1941

5. The Transfer Schedule of Soviet Land Combat Units, which were a Deployed (D) State, to the USSR's Western Fronts from 23rd June to 31st December 1941

1) The Siberian Divisions

6. The Actual Strength of all Soviet Land Combat Units in a Deployed (D) State on 22nd June 1941

1) Review of the Overall Strengths of Selected Red Army Units and PVO forces on 22nd June 1941

a. The Rifle Divisions

b. The Mechanised Corps

c. The AT Brigades

d. The Fortified Sectors

e. The PVO Ground Forces

2) The Leningrad Military District (Northern Front from 24th June 1941)

a. Rifle Divisions

b. 1st Mechanised Corps

c. 10th Mechanised Corps

d. The Hango Peninsula Garrison

e. Leningrad Military District, Front, Army and Corps Support Units

f. Total Manpower and Equipment in the Leningrad Military District, 22nd June 1941

3) The Baltic Special Military District (Northwestern Front from 22nd June 1941)
   a. Rifle Divisions
   b. NKVD Rifle Divisions
   c. 5th Airborne Corps
   d. 3rd Mechanised Corps
   e. 12th Mechanised Corps
   f. Garrisons on the Islands of Oesel (Saaremaa) and Dago (Hiiumaa)
   g. Baltic Special Military District, Front, Army and Corps Support Units
   h. Total Manpower and Equipment in the Baltic Special Military District, 22nd June 1941
4) The Western Special Military District (Western Front from 22nd June 1941)
   a. Rifle Divisions
   b. 4th Airborne Corps
   c. 6th Cavalry Corps
   d. 6th Mechanised Corps
   e. 11th Mechanised Corps
   f. 13th Mechanised Corps
   g. 14th Mechanised Corps
   h. 17th Mechanised Corps
   i. 20th Mechanised Corps
   j. Western Special Military District, Front, Army and Corps Support Units
   k. Total Manpower and Equipment in the Western Special Military District, 22nd June 1941
5) The Kiev Special Military District (Southwestern Front from 22nd June 1941)
   a. Rifle Divisions
   b. Mountain Rifle Divisions
   c. 1st Airborne Corps

d. 5th Cavalry Corps
e. 4th Mechanised Corps
f. 8th Mechanised Corps
g. 9th Mechanised Corps
h. 15th Mechanised Corps
i. 16th Mechanised Corps
j. 19th Mechanised Corps
k. 22nd Mechanised Corps
l. 24th Mechanised Corps
m. Kiev Special Military District, Front, Army and Corps Support Units
n. Total Manpower and Equipment in the Kiev Special Military District, 22nd June 1941

6) The Odessa Military District (Including the 9th Separate Army)

a. Rifle Divisions
b. Mountain Rifle Divisions
c. 3rd Airborne Corps
d. Cavalry Divisions
e. 2nd Mechanised Corps
f. 18th Mechanised Corps
g. Odessa Military District, Front, Army and Corps Support Units
h. Total Manpower and Equipment in the Odessa Military District, 22nd June 1941

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Appendix F

Table of Contents, Volume IIIB: The Soviet Armed Forces, Mobilisation and War Economy from June to December 1941

The following is the Table of Contents for Volume IIIB, scheduled to be published in 2013-14. It is subject to change, although any changes will comprise additional content.

***

6) Red Army Cavalry Units Mobilised from 22nd June to 31st December 1941
   a. Cavalry Divisions Mobilised from 22nd June to 31st December 1941
   b. Mountain Cavalry Divisions Mobilised from 22nd June to 31st December 1941
   c. Cavalry Corps HQs Mobilised from 22nd June to 31st December 1941
7) Red Army Mountain Units Mobilised from 22nd June to 31st December 1941
   a. Mountain Divisions Mobilised from 22nd June to 31st December 1941
8) Red Army Airborne Units Mobilised from 22nd June to 31st December 1941
   a. Airborne Brigades Mobilised from 22nd June to 31st December 1941
   b. Airborne Corps HQs Mobilised from 22nd June to 31st December 1941
9) Soviet Naval Ground Units Mobilised from 22nd June to 31st December 1941
   a. Naval Infantry Brigades Mobilised from 22nd June to 31st December 1941
   b. Naval Rifle Brigades Mobilised from 22nd June to 31st December 1941
10) NKVD Combat Units Mobilised from 22nd June to 31st December 1941
   a. NKVD Motorised divisions Mobilised from 22nd June to 31st December 1941
   b. NKVD Rifle Divisions Mobilised from 22nd June to 31st December 1941
   c. NKVD Border Regiments Mobilised from 22nd June to 31st December 1941

a. The Actual Strength of Soviet Naval Units in the Black Sea: June 1941

b. A Summary of Soviet Naval Operations and Naval Losses in the Black Sea: June to December 1941

4) The Northern Fleet

a. The Actual Strength of Soviet Naval Units in the Arctic Region: June 1941

b. A Summary of Soviet Naval Operations and Naval Losses in the Arctic Region: June to December 1941

5) The Pacific Fleet

a. The Actual Strength of Soviet Naval Units in the Pacific: June 1941

b. A Summary of Soviet Naval Operations and Naval Losses in the Pacific: June to December 1941

6) Separate Inland Waterway Flotillas

7) Soviet Naval Vessel Reinforcements: July to December 1941

Selected Bibliography

As a complete work with six distinct volumes *, Operation Barbarossa: Complete Organisational and Statistical Analysis, and Military Simulation* uses several hundred published and unpublished sources and references. Therefore the bibliography (below) only pertains to those sources directly referenced in Volume I.

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One of the objectives of this work is to formalise a generic analytical methodology for creating a realistic model of a country's armed forces, mobilisation, war-economy and military proficiency. In later volumes of this work, this methodology is then applied to the belligerents on the East Front during 1941, and can be used (if desired) to create a realistic simulation of Operation Barbarossa. With this in mind a Fully Integrated Land and Air Resource Model (FILARM), or a Partially Integrated Land and Air Resource Model (PILARM), will be created for all the combatants involved on the East Front from 22nd June to 31st December 1941; a period of 193 days. [156] One of the key foundations of the integrated land and air models is the concept of 'resources'. This is a rather clinical way of describing the mass of people and equipment involved in making up the particular armed forces involved. The integrated land and air models need to represent all resources present at the start of the campaign, and all resources received from all sources during the campaign period. These resources are therefore the basic building blocks to be used in all model construction.

Accordingly, in each country's FILARM or PILARM model the initial chapters are concerned with reviewing, analysing and defining the specific resources that were available to that country from June 1941 to January 1942. The resultant list of defined resource entities is termed the ' Personnel and Equipment Resource Database', or simply the ' Resource Database', for that country.

Volume I, Part II of this work is concerned with defining what the individual resource entities contain in the Resource Database, and the methodology used to calculate each resource entity's attribute values. Although the methodology detailed here is generic (it can be applied to any weapon system or organisation), the focus is on technology from the first half of the twentieth century, and primarily on weapons and organisations from WWII.